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WORK OF SOVIET SOIL SCIENTISTS AND AGRICULTURAL CHEMISTS FOR THE XXII MEETING OF THE COMMUNIST PARTY OF THE USSR

Soil scientists and agricultural chemists, as well as the millions of people in our country, were inspired by the resolutions of the latent Plenums of the Central Committee of the Communist Party of the USSR — directed toward the improvement of agriculture, and the fulfillment of important tasks for the further rational utilization of one of the major riches of the country — soils.

The soils of our immense country are the basic materials of agriculture, designed to satisfy the needs of the peoples of the Soviet Union in food products and various industrial raw materials for our industry.

A thorough knowledge of soil properties and of the principles of their distribution in individual republics, oblasts', rayons, and farms is necessary for the further increase in agricultural production, the rational distribution of its individual professions, and the fulfillment of the tasks set by the Party and the Government for the future.

An important role in the solution of these problems facing socialistic agriculture is played by soil scientists and agricultural chemists who study soils and develop rational methods for reclaiming them.

In honor of the XXII Meeting of the Communist Party of the USSR soil scientists and agricultural chemists took on important obligations ensuing from the tasks set before our agriculture by the 7-year plan for the development of the national economy, keeping in mind the historical words of N. S. Khrushchev that "...the fight for steady improvement of agriculture is an important condition for the development of the communist society and a matter concerning all the people..."¹ "...Agricultural production must be organized in such a manner that it would guarantee our obtaining the necessary products to satisfy the needs of the people every year and under any climatic conditions."²

¹ N. S. Khrushchev. Increase in the welfare of the people and tasks for further improvement in the output of agricultural products. Speech at the Plenum of the Central Committee of the Communist Party of the USSR on January 17, 1961. *Gospolitizdat*, 1961. pp. 9-10.

² Ibid, p. 15.

The successful fulfillment of these tasks depends greatly on our knowledge of soils, their highly varied properties, their natural productivity level, and the development of scientific methods of their rational utilization. It is difficult to organize agricultural production properly to satisfy the present needs of national economy without the detailed study of these soil characteristics.

It must be noted that the high level of development of soil science and agricultural chemistry in our country was instrumental in obtaining valuable data for the solution of these problems. The work of prominent scientists in the field of agriculture, and the founders of these sciences, such as V. V. Dokuchayev, P. A. Kostychev, V. R. Vil'yams, K. K. Gedroyts, D. N. Pryanishikov, and others, and their followers — the many generations of Soviet soil scientists and agricultural chemists — served as a basis for the further development of the theory and practice of our socialistic agriculture.

One of the next tasks of soil science consists of creating a scientific foundation based on theoretical studies, for practical measures of increasing the effectiveness of fertilizers, for melioration, and for the utilization of the natural fertility of soils. Without the development of theory and the improvement of methods it is impossible to solve successfully the major problem in soil science and agricultural chemistry, which is to increase the yield of all agricultural crops. A close connection between theory and practice, science and production, and the coordination between studies conducted by soil scientists and agricultural chemists are important prerequisites for the successful and rapid solution of the foregoing task.

Problems of the rational reclamation of soils and the increase of their productivity occupy an important place in the tasks of soil and agricultural chemical institution. These tasks involve the following:

1. The study of land resources, their site quality, and their further rational utilization.
2. The development of soil reclamation methods in irrigated regions.
3. The control of erosion and other harmful processes which lower soil productivity.

4. The development of agricultural chemical and technical agricultural practices for increasing the yield from fields.

The long-term studies by the Soil Institute on the compilation of a State soil map and the assessment of the land resources of the USSR belong to this category of work. The volume of studies conducted in honor of the XXII meeting of the party is tremendous and difficult to evaluate. We can only note that these studies served as a basis for planning the reclamation of virgin and abandoned lands in recent years, for the national-economical regionalization of the USSR, and for finishing a general assessment of the land resources necessary for planning organizations.

These fundamental studies deepened our knowledge of soil and were instrumental in the solution of many problems of soil genesis and classification. They have been highly praised in our country as well as abroad (VII International Congress of Soil Science in the U. S. A. etc.).

In the course of these studies a project is being developed on the general systematization of the soils of Central and Eastern Siberia and the Far East. This will undoubtedly promote the proper utilization of land resources.

The success of extensive cartographic soil studies made it possible to resume the site quality study of soils in recent years (Dokuchayev Soil Institute, Ministry of Agriculture of the USSR, and a number of regional and union institutions). Major principles and methods for the study of the site quality of soils have been developed, while a number of republics and oblasts³ have completed this work (Latvian SSR, Tomsk Oblast', etc.).

The soil scientists of the Union have acquired tremendous experience in the reclamation of agriculturally valuable virgin lands and have begun a new, even more important phase of work — the large-scale mapping of all the land to be reclaimed for kolkhozes and sovkhozes.

At the present time the soil scientists of the Ukraine have successfully completed this work, and it is being completed in other Union republics, while in the RSFSR this work must be finished in the next few years.

The V. V. Dokuchayev Soil Institute and the All-Union Institute of Fertilizers and Agricultural Soil Science (VIUA) assumed the scientific-methodological task to assure work of high quality.

The Timiryazev Moscow Agricultural Academy (TSKHA) and the Moscow State University (MGU) continue the study of virgin and abandoned lands in the Virgin Province of the Kazakh SSR, where they investigated about 10 million hectares of land, now being used by grain growing sovkhozes.

In honor of the XXII meeting these institutions and the V. R. Vil'yams Museum pledged to conduct detailed soil investigations in kolkhozes and sovkhozes of the Arkhangel'sk, Smolensk, and Ryazan' Oblasts', and the Virgin

Province (TSKHA) over an area of 1170,000 hectares. The Moscow State University agreed to compile maps of the Shumyachi rayon, Smolensk Oblast', and to develop methods for increasing soil fertility and the productivity of land under various agricultural uses.

The last Plenum of the Central Committee of the Communist Party of the USSR has noted that scientific achievements are not yet fully utilized in agricultural practice. It became necessary to organize a network of experimental demonstration farms to remedy this situation. The tasks of these farms is to check and introduce scientific methods and to further develop theoretical and practical methods for increasing the productivity of fields. The networks of experimental demonstration farms open a wide field of activity for our scientific institution. At these farms conditions will be created for the rapid introduction of all the experience gained by scientific institutions in the past years. At the same time, scientific institutions will find a basis for the further development of new ideas and methods for the rational reclamation of soils. These farms will provide unlimited possibilities for verifying everything that might effectively increase the productivity of fields.

Many central and peripheral scientific soil and agricultural chemical institutions will be involved in this work. Thus, the V. V. Dokuchayev Soil Institute, the All-Union Institute of Fertilizers and Agricultural Soil Science, and the Timiryazev Moscow Agricultural Academy agreed to take part in the selection of experimental demonstration farms, typical for the regions they are meant to serve.

The V. V. Dokuchayev Soil Institute has already started experimental work at several such farms. It includes studies on the reclamation of solonchets under dry-land farming and irrigated conditions in the Kazakh SSR and the Kalmyk ASSR, studies in the Moscow Oblast' ("Yakhromskiy" sovkhoz) on the rational utilization of peat soils, and helps individual farms in the Serebryanoprud rayon to increase soil productivity.

This work involves an ever increasing number of scientific institutions, which we cannot possibly list here.

Great tasks face soil scientists on the problem of irrigated soils. "...The most reliable means of obtaining stable crop yields, until we learn to control the weather, is irrigation — the irrigation of millions of hectares..."³

With respect to these tasks the V. V. Dokuchayev Soil Institute took on the responsibility of determining the possibility of reclaiming soils of the Volga-Akhtuba flood plain and the Volga delta in relation to the planned irrigation of this area. These studies are being conducted now. Similar work is being expanded in the area of the Trans-Volga region to be irrigated in the future. The salinization and desalinization

³ N. S. Khrushchev. Speech at the January Plenum of the Central Committee of the Communist Party of the USSR.

of soils in Central Asia are being studied using new methods of irrigation and drainage. This problem also involves the reclamation and melioration of solonchik lands and the development of agricultural methods of reclaiming the semi-desert of the Trans-Volga region.

The Soil Biology Faculty of Moscow State University took on the task of generalizing the results of studies on the flood plain in the Don and Don-Salmanykh watershed. This will promote the further improvement of soil irrigation and the rational distribution of irrigated agricultural crops. The Faculty also pledged to finish work on the characterization of soil from the agricultural-meliorative point of view in the area of the hydroelectric power station on the lower Volga and in the Chapayev and Pri-Volga rayons of the Kuybyshev Oblast'. In honor of the XXII meeting of the Communist Party of the USSR the primary task of the Soil Institute in the field of soil erosion control is to organize and supervise the introduction of zonal water and wind erosion control measures (called for by a decree of the Council of Ministers of the RSFSR) and the preparation for publication of the scientific-popular pamphlet "Erosion, droughts and their control in the central chernozem regions." A number of peripheral scientific institutions also pledged to control soil erosion in individual territories of the Union, and are successfully conducting this work.

In the fields of agricultural chemistry and agricultural practices, central scientific-research institutions took on a number of serious tasks concerning the compilation of instructions on agricultural chemical mapping, the development of accelerated methods of chemical soil analysis, the diagnosis of nutrition of plants, the use of agricultural chemical maps in kol-khozes and sovkhoses, the increase of the productivity of sod-podzolic soil by deep plowing, and the development of systematic practices for improving the moisture regime of soils in the Altay Province (V. V. Dokuchayev Soil Institute).

The Soil Department of the Soil Biology Faculty of Moscow State University pledged to conduct field tests on domestic gibberellin to determine its effect on the growth, development, and yield of certain crops, to develop new methods of increasing soil productivity and the effectiveness of fertilizers in the non-chernozem belt, and to continue the study of flood-plain soils for the purpose of obtaining high and steady crop yields on them.

Moreover, pledges were made to elaborate the soil maps of the Moscow Oblast' in relation to the new tasks of agriculture in this region (Soil Institute), to study soil conditions in the park area of the future Palace of Soviets (Moscow, Moscow State University), etc.

The further development of soil science and agricultural chemistry is unthinkable without the improvement of working methods, and without modern equipment and instruments for laboratory and field investigations. The process in physics, chemistry, biochemistry, and mineralogy, as well as industry has created favorable conditions for the use of modern methods and instruments in soil science and agricultural chemistry. These methods and instruments increase the level of theoretical investigations. If in the past, soil science was primarily based on observations of natural phenomena, on morphological descriptions, and the simplest analyses, now it is based largely on permanent studies of soil-formation processes and radio-isotope, X-ray, thermographic, electron-microscope, chromatographic, and spectral methods. The new methods made it possible to study more thoroughly the nature of organic and mineral substances composing the soil, to determine the principles of the distribution of microorganisms, humus, and minerals in the major soil groups, and to solve genetic problems at a higher level.

In the foregoing review of the pledges made by the soil scientists and agricultural chemists of the Union we showed only a few of the major problems being studied in honor of the XXII meeting of the Party by central and peripheral scientific soil science and agricultural and peripheral scientific soil science and agricultural chemical institutions, which illustrate the wide response of our soil scientists and agricultural chemists to the call of the Central Committee of the Communist Party of the USSR to meet the XXII session of the Communist Party of the USSR with the triumphant results of their work.

At recently held all-union meetings of scientists and members of institutions of higher learning, concrete tasks were assigned to Soviet science in order to fulfill the program of the construction of communism.

At an All-Union Meeting of scientists, comrade A. P. Kozygin said: "An important place in the scientific-research work on a state level must be occupied by research directed toward the determination of the most important principles and of new ways for mankind to harness the forces of nature." This important thought stresses the fact that science must foresee the problems which will be faced by agriculture in the future.

Our country has all the material means for increasing the level of agriculture and for supplying its people with a wealth of products. Soviet soil scientists and agricultural chemists will apply all their strength and knowledge to promote an even greater increase of agriculture and the development of soil science in our country.

NEW DATA ON QUALITATIVE STRUCTURE OF LAND UNDER VARIOUS AGRICULTURAL AND FOREST USES IN THE USSR ACCORDING TO SOIL CHARACTERISTICS

N. N. ROZOV

The present land assessment made by the organizations of the Ministry of Agriculture gives us exhaustive data on areas under various agricultural uses, on their agricultural categories, and on their use.

The qualitative characteristics of various agricultural land uses, as determined by the properties and productivity of the soils, had been neglected for a long time. Only in recent years, in relation to the reclamation of virgin and abandoned lands, have certain subdivisions of a qualitative nature, associated with soil characteristics, been introduced into the land uses being assessed. Thus, fields and abandoned lands are now being divided into excessively moist, peaty, solonetzic, and saline; and hay fields, in addition to being subdivided into flooded, dry, and water-logged, are now also being subdivided into solonetzic, saline, specially water-logged pastures, etc. These qualitative elements of land assessment do not give the necessary soil characterization of the major and most productive agricultural lands. Land on podzolic, chernozem, chestnut, and sierozem soils, as well as land with clay, clay loam, sandy loam, and sandy soils, remain quantitatively unassessed, as before, even though these characteristics determine their productivity and the complex of agricultural production practices.

Land resources can be qualitatively assessed according to soil characteristics using direct and indirect methods.

The direct method of assessing land resources is more accurate. It calls for large-scale soil maps covering the area to be assessed. These maps include, in addition to soil contours, the contours of lands under various uses. Now the same assessment can be made for the land under use in many kolkhoses and sovkhozes, having soil maps of their farms, and for certain administrative regions, having summarized regional soil maps. This method of assessment requires that all the administrative regions which practice agriculture and forestry obtain large-scale soil maps and that maps be compiled according to a unified classification system and nomenclature.

The widely used indirect method of assessing land resources is based on the use of medium- and small-scale soil maps. Their scale makes

it impossible to plot land contours on them, and therefore they are only used for the measurement and calculation of soil areas within the limits of the major units of agricultural soil regionalization (agricultural soil zones, subzones, and provinces). The regional statistical data on land uses are summarized on the basis of the same units.

A comparison of data and corresponding calculations make it possible to judge the agricultural utilization of the major soil groups and subgroups and the qualitative structure of land uses.

The method of indirect assessment of land resources according to soil characteristics was proposed by L. I. Prasolov. Soil zones and subzones — areas which are relatively homogeneous in their soil characteristics — were taken as a unit of combined assessment. These zones and subzones are easily compared with the material available at the Ministry of Agriculture on the assessment of soil areas and lands with an accuracy sufficient for this purpose.¹

Following this method we used the sheets of the State Soil Map of the USSR on a scale of 1:4,000,000 to measure soil areas. We compared the data obtained with the material available at the Ministry of Agriculture on land assessment. This study made it possible for us to judge the agricultural utilization of soil in the soil zones of the USSR and the qualitative structure of the major land uses on the basis of soil characteristics.²

Below we give the soil characteristics of:
1) plowland (including orchards, truck gardens,

¹L. I. Prasolov. Land resources for growing plants in the USSR from the point of view of soil geography. In the book: Growing plants in the USSR. Vol. 1, No. 1. Moscow-Leningrad, 1933. N. N. Rozov. Results and immediate tasks in the study of the land resources of the USSR. In the book: Problems of the genesis and geography of soils. Izd. Akad. Nauk SSSR, 1957.

²The work was conducted with the participation of the scientist O. A. Vadkovskaya and the cartographers V. N. Obodovskaya, M. S. Chevkina, M. N. Kalabina, and I. D. Manucharyan.

QUALITATIVE LAND STRUCTURE

and abandoned land); 2) hay fields; 3) grazing areas and ordinary pastures; 4) deer pastures; and 5) forest areas (including areas under shrubs, cut-over, and burned).

The numerical data are given in percentages of the total area occupied by the foregoing land uses.

Plowland

The present structure of plowland (including abandoned land, orchards, and truck gardens) formed in the process of the extensive land reclamation in recent years. In addition to the plowing of old abandoned land and bastard fallow (about 18 million hectares) about 23 million hectares of virgin land, mostly pastures located primarily in the forest-steppe and the steppe zones, have been incorporated into agriculture. According to approximate calculations the newly-reclaimed land is distributed in the following manner (Table 1).

The major reclaimed virgin lands are con-

Table 1

Soil characteristics of virgin lands converted to agricultural use in 1954

Soils	Area, millions ha
Sod-podzolic	1
Chernozems and gray forest	10
Dark-chestnut and chestnut	11
Various desert and mountain	1

centrated in Northern Kazakhstan, Western Siberia, and partly in the Lower Volga region. Special calculations made for 5 oblasts' in Northern Kazakhstan (Kustanay, Northern Kazakhstan, Kokchetav, Pavlodarsk, and Tselinograd) and in the Altay Province showed that about 7.5 million hectares of chernozem (3/4 of the newly reclaimed chernozems) and about 4 million hectares of dark-chestnut and chestnut soils have been reclaimed from virgin land and pastures in the foregoing regions.³

As a result of measures taken by the government on the reclamation of new lands, the percentage of plowland, located in the forest-steppe and steppe zone, has increased in the total balance of plowland from 68.7% to 70.9% since 1953, i. e., by 2.2%. The percentage of plowland in other zones has decreased correspondingly. Thus, the present qualitative structure of plowland in the USSR, according to zonal groups, is the following (Table 2 and Fig. 1): the taiga-forest zone includes 19.8% of the total plowland; the forest-steppe and steppe zones, 70.9%; the semi-desert and desert zones, 5.5%; and mountain regions, 3.8%. Let us examine each of these groups individually.

The group of taiga-forest plowlands is located predominantly on sod-podzolic soils (16.9% of the total plowland area of the USSR), which, according to our calculations made in cooperation with the Scientific-Research Institute

³ Natural regionalization of Northern Kazakhstan. Izd. Akad. Nauk SSSR, Moscow, 1960. Natural regionalization of the Altay Province. Izd. Akad. Nauk SSSR, Moscow, 1958.

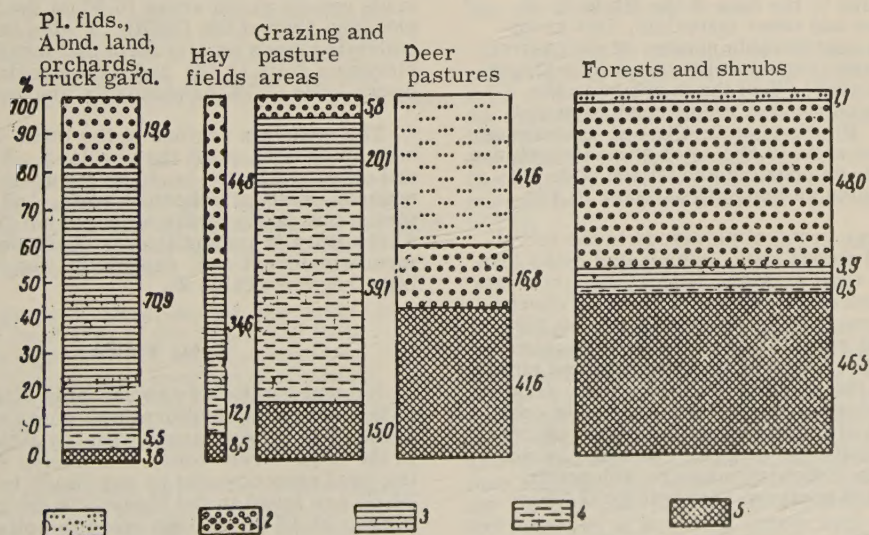


Fig. 1. - General qualitative structure of various land uses in the USSR, according to soil characteristics.

Zonal soil groups of land uses: 1 - tundra-arctic; 2 - taiga-forest; 3 - forest-steppe and steppe; 4 - semi-desert and desert; 5 - mountain regions.

Table 2

Qualitative structure of plowlands in the USSR, according to soil characteristics, including abandoned lands, orchards, and truck gardens

Agricultural soil zones	Soils	Area, % of total area under plowland	
Taiga-forest	Podzolic clay loams and illuvial-humus sandy loams	0.4	19.8
	Sod-podzolic clays and clay loams	12.2	
	Sod-podzolic sandy loams and sands	4.7	
	Sod-calcareous	0.8 ^a	
	Podzolic-bog and water-logged sod-podzolic	1.7	
Forest-steppe and steppe	Gray forest	11.8	70.9
	Podzolized, leached, and typical chernozems, and meadow-chernozems	22.8	
	Solonetzic meadow-chernozems	0.8 ^a	
	Ordinary and southern chernozems	24.5	
	Solonetzic chernozems	2.1 ^a	
	Dark-chestnut and chestnut	7.6	
	Dark-chestnut and chestnut solonetzic	1.3 ^a	
Semi-desert and desert	Light-chestnut and brown semi-desert	1.7	5.5
	Gray-brown desert and meadow-sierozems	0.4 ^a	
	Sierozems and meadow-sierozems	3.0	
	Solonchakized meadow-sierozems	0.4 ^a	
Mountain areas	Mountain podzolic and gray forest	0.8	3.8
	Brown forest mountain	0.8	
	Mountain chernozems, chestnuts and sierozems	2.2	
Total		100.0	100.0

^aApproximate data

of Fertilizers and Insecticides,⁴ includes 12.2% of plowed fields on clay and clay loam soils and about 4.7% of plowed fields on sandy loam and sandy soils.

According to the data of the Ministry of Agriculture and other materials, this group includes a considerable number of excessively wet and water-logged fields on various gleyey and gley soils (1.7% of the plowland in the USSR), which require runoff regulation and drainage. Plowland on fertile sod-calcareous and similar soils (0.8%) is of great importance. Agriculture on podzolic and frozen podzolic soils occupies an insignificant area (0.4%).

The large group of plowlands in the forest-steppe and steppe zone, comprising more than 70% of the total plowland of the USSR, consists of fields and other cultivated lands on chernozems and meadow-chernozem soils (50.2%), gray forest soils (11.8%), and dark-chestnut soils (8.9%). According to our data and similar data from the Ministry of Agriculture, fields and abandoned lands on solonetzic soils comprise 4.2% of the total land in these categories and are subdivided according to soil characteristics in the following manner: solonetzic ordinary and southern chernozems (2.1%),

solonetzic dark-chestnut and chestnut soils (1.3%), and meadow-chernozem solonetzic soils (0.8%).

In the semi-desert and desert zone plowlands occupy small areas (5.5% of the total plowland area of the USSR). Fields and other cultivated lands on sierozem and meadow-sierozem soils (3.4%) and light-chestnut and brown soils (1.7%) predominate among them.

The mountain regions of the USSR contain only about 3.8% of all the plowland. Fields and other cultivated lands on mountain chernozems, mountain chestnut soils, and mountain sierozems predominate among them (2.2%). Agriculture is insignificantly developed in the mountain-forest and, especially, the mountain-taiga regions (Table 2).

Hay Fields

Natural hay fields are unevenly distributed in the natural agricultural soil zones of the USSR. The largest areas with hay fields are found in the taiga-forest zone, comprising 44.8% of the total area covered by hay fields in the USSR, 34.6% are found in the forest-steppe and steppe zones, 12.1% on various meadow soils in the semi-desert and desert zone, and 8.5% in the mountains (Table 3).

The qualitative structure of hay fields, according to soil characteristics, varies in various

⁴ V. F. Kalganova of the Scientific-Research Institute of Fertilizers and Insectofungicides took part in this work under the supervision of A. V. Sokolova.

QUALITATIVE LAND STRUCTURE

Table 3

Qualitative structure of hay field in the USSR, according to soil characteristics

Agricultural soil zones	Soils	% of total area occupied by hay fields	
Taiga-forest	Podzolic and gley-podzolic	3.5	44.8
	Sod-podzolic clay loams and clays	15.5 ^a	
	Sod-podzolic sandy loams	6.9 ^a	
	Alluvial sod	8.6	
	Podzolic-bog and water-logged alluvial	10.3	
Forest-steppe and steppe	Gray forest	5.2	34.6
	Podzolized, leached, and typical chernozems, and meadow-chernozems	10.3	
	Ordinary and southern chernozems	5.2	
	Dark-chestnut, chestnut, and meadow-chestnut	5.2	
	Alluvial meadow	5.2	
	Meadow-bog	3.5	
Semi-desert and desert	Light-chestnut and meadow-chestnut	6.9 ^a	12.1
	Meadow-sierozem	1.7	
	Alluvial meadow	3.5	
Mountain areas	Mountain-meadow	3.4	8.5
	Mountain podzolic and gray forest	3.4 ^a	
	Mountain chernozems and chestnut	1.7 ^a	
Total		100.0	100.0

^aApproximate data

zonal groups.

In the group of taiga-forest hay fields, comprising 44.8% of the total area, dry hay fields on sod-podzolic and podzolic soils predominate (25.9%). Among these 22.9% are found on sod-podzolic soils and about 3.5% on podzolic and partly gley-podzolic soils. The approximate characterization by texture of dry hay fields on sod-podzolic soils is of certain interest. About two-thirds of these are clays and clay loams and about one-third are coarser sandy loam soils.

The second place after dry hay fields is occupied by water-logged hay fields on water-logged podzolic and other gley and gleyey soils comprising 10.3%, and the third place is occupied by flooded flood-plain hay fields, confined to alluvial-sod soils (8.3%).

In the group of forest-steppe hay fields (34.6% of the hay field area of the USSR) the first place is occupied by dry forest-steppe hay fields on chernozems, meadow-chernozems, and gray forest soils (20.7%). Dry steppe hay fields on dark-chestnut, chestnut, and meadow-chestnut soils are less extensive (5.2%).

Flooded flood-plain hay fields in this group also comprise 5.2% and water-logged hay fields, 3.5%. The last two categories of hay fields are primarily confined to alluvial-meadow and water-logged alluvial-meadow soils.

The group of hay fields of the semi-desert and desert zones covers a small area (12.1% of

the area under hay fields in the USSR). Dry hay fields on meadow-chestnut and meadow-sierozem soils predominate among them (8.6%). Flooded desert hay fields occupy a considerably smaller area (3.5%). All the desert hay fields are more or less solonchakized and have a complex soil, which has not been assessed yet.

The group of mountain hay fields of various categories is even smaller, comprising about 8.5% of the total hay-field area of the USSR. An important role in this group is played by hay fields on mountain-meadow soils (3.4%) and mountain podzolic and gray forest soils (3.4%). Hay fields on mountain-steppe chernozems and chestnut soils are less extensive (1.7%).

Pasture and Grazing Areas

Pasture and grazing lands can be divided into four zonal groups according to the nature of the soil (Table 4), among which the largest area is occupied by semi-desert and desert pastures, comprising 59.1% of the total pasture area of the USSR, without counting deer pastures – next are steppe and forest-steppe pastures (20.1%), then mountain pastures of various types (totaling 15.0%), and, finally, the grazing areas and pastures of the taiga-forest zone (5.8%).

Below we will examine the qualitative structure of pasture lands according to their soil characteristics in the natural sequence from north to south.

Table 4

Qualitative structure of pasture lands in the USSR, according to soil characteristics
(excluding deer pastures)

Agricultural soil zone	Soils	% of total area under pasture	
Taiga-forest	Podzolic (including alluvial sod)	1.0 ^a	5.8
	Sod-podzolic (including alluvial sod)	3.5	
	Bog-podzolic and water-logged alluvial	1.3	
Forest-steppe and steppe	Gray forest	0.6	20.1
	Podzolized, leached, and typical chernozems (mostly eroded)	1.6	
	Solonetzic meadow chernozems and solonetztes	1.3 ^a	
	Water-logged alluvial-meadow	0.6 ^a	
	Ordinary and southern chernozems (mostly eroded)	1.0	
	Solonetzic chernozems and solonetztes	1.9 ^a	
	Stony chernozems	1.9	
	Dark-chestnut and chestnut	3.2	
	Solonetzic dark-chestnut and chestnut and solonetztes	6.7 ^a	
	Stony dark-chestnut and chestnut	1.3 ^a	
Semi-desert and desert	Light-chestnut and brown semi-desert	10.5	59.1
	Solonetzic light-chestnut and brown semi-desert and solonetztes	17.6 ^a	
	Light-chestnut and brown semi-desert stony	1.3 ^a	
	Gray-brown desert	10.8	
	Overtgrown desert sands	9.0 ^a	
	Sierozems	4.8	
	Alluvial-meadow and meadow sierozems (mostly solonchakized)	5.1	
Mountain regions	Mountain-meadow	5.8	15.0
	Podzolic mountain and gray forest	0.6	
	Mountain brown forest	0.3	
	Mountain chernozems, chestnut, and sierozems	8.3	
Total		100.0	100.0

^aApproximate data

The qualitative structure of taiga-forest grazing areas and pastures is very simple. Of their total area, comprising 5.8%, 3.5% is found on sod-podzolic soils, 1.3% on bog-podzolic and water-logged alluvial soils, and only 1% is occupied by podzolic soils.

Forest-steppe and steppe pastures, occupying about 20.1% of the pasture area of the USSR, have a much more complicated qualitative structure. Four series can be distinguished among them according to soil characteristics.

The first series comprises pastures on soils exhibiting no signs of solonetzization or stoniness. This series includes pastures on gray forest soils (0.6%), on podzolized leached and typical chernozems (1.6%), on ordinary and southern chernozems (1.0%), and on dark-chestnut and chestnut soils (3.2%), 6.4% altogether.

The second series consists of pastures on solonetzic soils: on solonetzic meadow-chernozems and solonetztes (1.3%), on solonetzic chernozems and solonetztes (1.9%), and on solonetzic dark-chestnut soils, solonetzic chestnut soils, and solonetztes (6.7%), a total

of 9.9%.

The third series comprises pastures on stony soils: on stony chernozems (1.9%) and stony dark-chestnut and chestnut soils (1.3), a total of 3.2%.

Finally, the fourth series consists of pastures on waterlogged alluvial-meadow soils and meadow-bog soils (0.6%).

These characteristics refer to the total area under pasture in the USSR.

The foregoing detailed analysis of forest-steppe and steppe pastures with respect to soil shows that the majority of these pastures are of little use or are completely unsuitable for agricultural utilization because of unfavorable soil characteristics. They are located primarily on sloping and steep slopes, where plowing causes severe soil erosion.

The group of semi-desert and desert pastures, comprising 59.1% of the area under pastures in the USSR, includes semi-desert pastures on semi-desert, non-solonetzic light-chestnut and brown soils, and sierozems (15.3%), on semi-desert solonetzic light chestnut and brown soils, and solonetztes (17.6%), and on semi-desert light-

QUALITATIVE LAND STRUCTURE

Table 5

Qualitative structure of deer pastures in the USSR, according to soil characteristics^a

Agricultural soil zones	Soils	% of the total area of deer pastures	
Tundra-arctic	Arctic and arctic tundra Tundra gley (subarctic)	15.3 26.3	} 41.6
Taiga-forest	Gley-frozen-taiga, gley-podzolic, and podzolic illuvial-humic	16.8	
Mountain regions	Mountain-tundra	39.5	} 41.6
	Mountain frozen-taiga	2.1	
Total		100.0	100.0

^aApproximate data

Table 6

Qualitative structure of forest areas in the USSR, according to soil characteristics^a

Agricultural soil zones	Soils	% of the total area under forests	
Tundra-arctic	Tundra	1.1	1.1
Taiga-forest	Gley-frozen-taiga	3.7	} 48.0
	Frozen-taiga	10.9	
	Gley-podzolic clays and clay loams	4.9	
	Gley-podzolic and podzolic illuvial-humic sandy loams and sands	3.7	
	Podzolic clay and clay loam	4.7	
	Podzolic sandy loam and sands (including sods of Kamchatka)	4.6	
	Sod-podzolic clay and clay loam (including podzolized brown forest)	10.9	
	Sod-podzolic sandy loam and sands	4.6	
Forest-steppe and steppe	Gray forest	3.1	} 3.9
	Podzolized and leached chernozems (including solods)	0.6	
	Alluvial meadow	0.2	
Semi-desert and desert	Desert sands	0.5	0.5
Mountain regions	Mountain frozen-taiga	31.6	} 46.5
	Mountain podzolic and gray forest (including mountain sods of Kamchatka)	13.2	
	Mountain brown forest	1.7	
Total		100.0	100.0

^aApproximate data

chestnut and brown stony soils (1.3%), a total of 34.2%. Special categories consist of desert pastures on gray-brown desert soils and sands (19.8%) and pastures on alluvial-meadow and meadow-sierozem soils (5.1%).

An approximate calculation does not permit us to evaluate accurately the extent of pasture land suitable for agriculture under irrigated conditions. It shows, however, that there are

considerable lands unsuitable for reclamation. They are occupied by stony solonchak, solonchak, and sandy soils.

The group of mountain pasture lands varies in its soil characteristics and comprises 15.0% of the pastures of the USSR. More than half of this group consists of mountain-steppe and mountain-semi-desert pastures on mountain chernozems, mountain chestnut soils, and

mountain sierozems (8.3%). Next are alpine and subalpine pastures on mountain-meadow soils (5.8%), and only a small part of this group consists of mountain-forest pastures and grazing areas on brown mountain soils, gray mountain soils, and podzolic mountain soils.

Deer Pastures

Only in recent years have deer pastures over wide areas been assessed as land use. The total areas of various types of deer pastures, assessed in recent years, is very large (more than 300 million hectares). There are only preliminary data on their qualitative structure according to soil characteristics.

According to these data, 41.6% of the total area of deer pastures are found in the tundra-arctic zone (Table 5). Of these 15.3% are on arctic and arctic tundra soils and 26.3% on gley tundra (subarctic) soils.

About 16.8% of the deer pastures are found in the subzone of the northern taiga, including the pre-tundra sparse forests. They are located primarily on gley-frozen-tundra soils of Eastern Siberia and partly on the gley-podzolic soils of the European North.

Finally, extensive areas with deer pastures (41.6%) are found under mountain conditions on mountain-tundra and partly on mountain-frozen-taiga soils.

Forests and Shrubs

Even though forest areas, including forests, shrubs, cut-over and burned areas, are found in all the natural zones of the USSR, they are distributed unevenly with respect to zonal geography.

About 48.0% of all the forests and shrubs are found in the plains of the taiga-forest zone, about 46.5% in the mountains, 3.9% in the forest-steppe and steppe zones, about 1.1% in the tundra, and less than 0.5% in the semi-desert and desert zones (Table 6).

Forests and shrubs in the tundra zone are confined to its southern limit and are found primarily in river valleys on alluvial-sod and partly on podzolized tundra soils. At the present time we do not have enough material to determine to exactly which soils they belong.

The qualitative structure of forests and shrubs in the level part of the taiga-forest zone, judging by soil characteristics, is better now. These forests comprise about 48.0% of the forests of the USSR and consist of four major soil-ecological categories on the following soil textures.

Forests, sparse forests, and shrubs on gley-frozen-taiga and frozen-taiga soils comprise 14.6% of the total and are found primarily on clays and clay loams. Forests, sparse forests, and shrubs on gley-podzolic and illuvial-humus soils comprise 8.6%, of which more than one-third is located on sandy loams and sands. Forests and shrubs (of the intermediate taiga type) on podzolic soils and podzols comprise 9.3%,

half of which are found on coarse deposits and sands. Finally, forests and shrubs on sod-podzolic soils (of the southern taiga type and coniferous — broadleaf forests, including secondary forests) comprise 15.5% of the total forest area of the USSR. More than two-thirds of these are located on clays and clay loams and only less than one-third on coarse deposits and sands.

The forests and shrubs of the forest-steppe and steppe group (broadleaf forests of the European USSR and narrow-leaf forests in Siberia) occupy a limited area, comprising only 3.9% of the total forest area of the USSR. They are confined primarily to gray forest soils (3.1%), to a lesser degree to podzolized and leached chernozems, including solods (0.6%), and also to alluvial-meadow soils (0.2%).

The forest and shrubs of the desert group occupy a small area (less than 0.5%). They consist either of saksaul forests on sands, or of tugay growths on alluvial-meadow soils.

The group of various mountain forests is extensive, occupying 46.5% of the forest area of the USSR. This group consists first of all of the low-production, primarily larch mountain forests of Eastern Siberia on mountain frozen-taiga soils (31.6%). Then come mountain forests, predominantly of the taiga type on mountain podzolic soil, acid non-podzolic mountain soil, sod-taiga mountain soil, and gray forest mountain soil (13.2%). These forests are found in the Urals, and the Altay, Sayan, and the Pacific Coast.

Finally, there are highly productive coniferous broadleaf forests on the brown forest soils of the Carpathians, the Crimea, the Caucasus, and the Far East, comprising a total of 1.7% of the forest areas of the USSR.

The foregoing data on the qualitative structure of areas under major land uses in the USSR, depending on their soil characteristics, show quite clearly the typical features of agricultural and forest lands in the USSR, even though they are based on approximate calculations. They may be separated into groups of lands with various soil productivity potentials, needing various agricultural and meliorative practice for obtaining higher yields.

These data also make it possible (in conjunction with other material) to examine the problem of the rational transformation of lands and the utilization of pasture and forest lands with the best soil conditions for agriculture in the nearest or far future.

We hope that further studies on direct qualitative land assessment, using the data in large-scale soil maps, will make it possible to elaborate many data and make a similar assessment not only for the entire USSR, but also for its major economical regions, republics, and oblasts'.

USE OF FERTILIZERS AND THE INCREASE IN GRAIN PRODUCTION DURING THE CURRENT SEVEN-YEAR PLAN

P. G. NAYDIN

The production and creation of the necessary grain supply in our country has been and still is one of the most important national economical and political undertakings. The Communist Party and the Soviet Government have always attached great importance to this task, realizing that grain is the basis of the entire agricultural production.

The most important measure taken in recent years to increase grain production was the plowing and reclamation of virgin lands in the east, which led to a considerable increase in the area under grain crops.

Extent of the area under grain crops, million ha

	1913	1940	1950	1953	1959	1960
Within the present borders of the USSR	104.6	110.6	102.9	106.7	119.7	121.7

The Soviet Union occupies the first place in the world according to the area under grain crops. More than 20% of the world area under grain crops is in our country.

The expansion of areas under grain crops after the historic resolutions of 1953 was accompanied by great changes in the structure and geography of areas under these crops. The proportion of the most valuable and productive crops increased considerably. The area under wheat (winter and spring) more than doubled during this period and reached 65.4 million hectares by 1960, which is one-third of the area under wheat in the whole world.

The expansion of the area under corn (the most productive grain crop) helped to increase the total grain crop yields. The total area under corn of all varieties was 22.4 million hectares in 1959, and 28.2 million hectares in 1960, as against 3.5 million hectares in 1953.

The January 1961 Plenum of the Central Committee of the Communist Party of the USSR noted that grain production in the country has increased by more than 3 billion poods (i. e., by almost 50 million metric tons) in the 7 years since 1953, while government purchases have increased by almost a billion poods. The

production of meat and milk will also increase considerably. Never before has our country seen such an increase in the development in agricultural production as in the last 7 years.

However, the Plenum realizes that, in the interest of communistic construction, the continued increase in the people's standard of living requires a more rapid development of agriculture. Agricultural production should always exceed the demand of the people. Without a developed agriculture and without an ample supply of agricultural products there cannot be a prosperous socialist economy. In his speech before the Plenum, comrade N. S. Khrushchev again stressed the point that "...an increase in the grain economy plays a decisive role in agricultural production, as does livestock industry".¹

The further increase in grain production during the current 7-year plan must be achieved primarily because of an increase in yield. The yield of grain crops in the Union is increasing slowly at present, still remaining at a low level.

Grain crop yield in all types of farms, %

1949-1953 annual average	1953	1954-1958 annual average	1959	1960
100	99	119	136	142

The January Plenum of the Central Committee of the Communist Party of the USSR (1961) concretely determined the major reserves in the development of the grain economy. Those are: the increase in corn production, the improvement of the productivity and further land reclamation in virgin areas, the increase in planted areas and, especially, the increase of productivity in the non-chernozem belt, as well as the increase in the yield of grain crops in all the regions of the country by improved agricultural practices.

As far as grain crop production is concerned the USSR still lags behind a number of West

¹N. S. Khrushchev. Collection of speeches on "The increase in the standard of living of the people and the further increase in the output of agricultural products," p. 35, 1961.

European countries. The great increase in yields in the U. S. A., which took place in recent years, was possible because of the extensive use of mineral fertilizers. In England and Germany, where the wheat yield from 1956-1959 averaged 30-32 cntr/ha, 6-9 cntr of mineral fertilizers were used per hectare. Even more mineral fertilizers were used in Holland, where the average wheat yield is 37 cntr/ha.

The sharp increase in the utilization of mineral fertilizers in the U. S. A. to 27-28 million metric tons in 1958 as against 5.9 million metric tons in 1938 undoubtedly had an effect on the yield of grain crops (from 8.7 cntr/ha of wheat in 1938 to 14.2 cntr/ha in 1959, and from 14 cntr/ha of corn to 37.3 cntr/ha of corn during the same years).

The lag in production of grain crops in the USSR is attributable to low soil fertility in many regions of our country and to insufficient use of fertilizers. Especially low grain crop yields are obtained in kolkhozes and sovkhoses of republics located in the non-chernozem belt of the USSR, on podzolic soils poor in nutrients under relatively favorable climatic conditions.

"At the present time the grain crop yield in the kolkhozes and sovkhoses of our country averages 10-11 cntr/ha," said N. S. Khrushchev at the January Plenum of the Central Committee of the Communist Party of the USSR (1961). "If we give the required amount of mineral fertilizers, then the same areas will produce 25-30 cntr/ha."²

The extensive use of fertilizers for the increase of grain crop yields was hampered by wrong ideas on the importance of fertilizers for grain crops and the low production of mineral fertilizers in our country.

Until recently many people thought that fertilizers (organic and mineral) do not increase grain crop yields in a number of very important agricultural regions (the chernozems of the Ukraine, the Northern Caucasus, the Southeast, and Siberia), and that mineral fertilizers have a doubtful effect on podzolic soils in fields not having been under grass. Now these ideas have been refuted by experiments conducted by Soviet scientific institutions and by the experience gained at leading kolkhozes and sovkhoses. The myth on the inexhaustible supply of nutrients in chernozems has long since been discarded by fundamental studies conducted at experiment stations.

The main findings of the regional station in Kharkov, for instance, on the high effect of manure and phosphorous fertilizers on thick chernozems, led D. N. Pryanishnikov to say in 1924 in a paper on "The problem of the introduction of chemistry in our agriculture" that "chernozem requires fertilizers, except for the southern and southeastern steppes."

Extensive geographical experiments with fertilizers, conducted in recent years, confirm this statement of Pryanishnikov completely, with only one correction — the chernozems and chestnut soils of the South and Southeast also require fertilizers.

Now we know that the Soviet Union does not have soils on which properly used fertilizers do not have a positive effect on the yield and quality of grain crops.

In order to obtain high and consistent grain crop yields we must first of all use manure and other local organic fertilizers in all the regions of the country. Manure is the most powerful and best known means of increasing the yield of all crops, including grain crops. It will always retain its importance as a fertilizer which affects soil fertility in many ways. The tremendous progress in the mechanization of field work in Soviet grain economy created a good basis for the more effective utilization of manure than was possible previously.

Numerous zonal institutes and experiment stations developed methods for the rational utilization of manure, which are suited to the soil-climatic peculiarities of the most important regions of our country. However, manure is not sufficiently used as a fertilizer in our country. Less than 2 metric tons of manure per hectare were used on the average in the USSR in 1960, while in the non-chernozem belt of the RSFSR about 3 metric tons were used. In the German Democratic Republic, in Czechoslovakia, and in other West European countries an average of 8-10 metric tons of manure are applied to each hectare.

The lack of manure in our country is due to low grain crops and grass yields, and consequently to the lack of forage and litter, which limit the development of livestock industry and the possibility of accumulating and properly storing manure. The increased supply and use of manure in Western Europe is attributable to the use of larger amounts of mineral fertilizers, which promotes the increase of forage and litter and the rapid development of livestock. The vicious cycle — lack of manure and consequently low grain and forage crop yield — was broken by the extensive use of mineral fertilizers.

We must admit that the full utilization of manure in many kolkhozes and sovkhoses is hampered by the lack of loading, storing, and distributing machines, as well as by the lack of equipment to deliver manure to the fields. Forest-free regions have a lot of manure, which accumulates on the personal farms of kolkhoz workers and is used for heating. In the last 3-4 years the export of manure and the use of peat for fertilizer have increased considerably as a result of the increase in livestock and the increased level of agriculture.

The production level of mineral fertilizers in the USSR made it impossible, until now, to use them in noticeable amounts for increasing grain crop yields. Even though the USSR occupies first place in Europe and second place in the world in the production of mineral fertilizers (which reached 13.8 million metric tons in 1960),

²N. S. Khrushchev. Collection of speeches on "The increase in the standard of living of the people and further increase in the output of agricultural products," pp. 19-20, 1961.

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the area under grain crops supplied with nitrogen fertilizers is still only 2%-3%, and that supplied with phosphorous fertilizers, 8%-10%. As we know, sufficient amounts of mineral fertilizers were supplied only to plantings of the major industrial and subtropical crops, primarily cotton, sugar beet, and tea. This was the decisive factor for obtaining good and ever increasing yields from these crops.

In the current 7-year plan the situation with the use of mineral fertilizers is changing considerably. The resolutions of the XXI meeting of the Communist Party of the USSR call for the production of 35 million metric tons of mineral fertilizers and the use of 31.0 million metric tons of fertilizers in agriculture, which is 150 times higher than the amount used in pre-revolutionary Russia.

Consumption of mineral fertilizers in the USSR

	1913	1928	1940	1953	1958	1960	1965
Total amount of mineral fertilizers supplied (as reduced to conventional units), thousand metric tons	188	248	3159	6569	10620	11410	31000

The use of mineral fertilizers in the USSR during the next 7-year plan will increase at least 3 times as compared to that in the last year of the last 5-year plan. By 1965 about 90,000 metric tons of mineral fertilizers will be supplied to agriculture annually. We will produce more mineral fertilizers in 2 days than was used annually in old Russia. The total volume of mineral fertilizers used in the USSR at the end of the 7-year plan will exceed by far that of capitalistic countries having a developed chemical industry.

The resolutions of the January Plenum of the Central Committee of the Communist Party of the USSR (1961) call for a great increase in the production and use of mineral fertilizers. The Plenum has recognized that one of the most important and urgent tasks is to increase the production of mineral fertilizers. It was decided to increase the appropriation of more money than was provided in the 7-year plan for the development of agriculture, as well as the industry serving agriculture, including that producing mineral fertilizers. The importance of the latter in the total balance of fertilizers and in the agricultural means for increasing the yield of all crops in our country has increased sharply.

The level of mineral fertilizer utilization, established for the 7-year plan by the resolutions of the XXI meeting of the Communist Party of the USSR, will make it possible to satisfy the requirement of all industrial crops for mineral fertilizers over an area of 10 million hectares (for which 8-9 million metric tons of mineral fertilizers will be needed).

For the first time in the history of our agriculture, mineral fertilizers will play an important role in the increase of grain crop yields in our national economy (as well as other foods and forage). At least 10 million metric

tons of mineral fertilizers can be delivered for grain crops (including corn), i. e., the same amount (or even more) as for industrial crops, and approximately the same amount as is now being used by the entire agriculture of our country. On the basis of results of long-term experiments we can expect that 10 million metric tons of mineral fertilizers will have the same effect as 200 metric tons of manure.

However, the tremendous areas under grain crops in our country, as well as the variety of soil-climatic conditions in which they are located, require a clear determination of the regions requiring mineral fertilizers and the determination of the most effective methods of adding them to the soil. These are the most important problems concerning the use of mineral fertilizers in our country which must be solved in

the current 7-year plan. The efforts of scientific institutions of the Soviet Union in the last 15-20 years have basically prepared the practical solution of these problems. We know that the tremendous territory of our country and its varied natural conditions (from tundras to deserts) will require special ways of using mineral fertilizers, from those followed by capitalistic countries, which developed mineral fertilizer production before we did.

In this connection we should be reminded of the advice given by D. N. Pryanishnikov that we should use the historical experience gained in Western Europe in the development of agriculture. We should by no means ignore it, but follow our own ways. "Our task consists of overtaking and surpassing the economically leading capitalistic countries as quickly as possible, and we can and must do it using all the possibilities available for the development of socialistic agriculture, without copying blindly some ready samples."³

By using all the advantages of a planned economy, we must direct mineral fertilizers into such regions in which the set level of grain crop production cannot be reached otherwise and where natural conditions are most favorable to the effective use of fertilizers. The level of natural soil productivity changes greatly in the USSR. This can be seen, for instance, by comparing the winter grain crop yields, obtained by experiment stations in the European USSR on control plots (without any fertilizers), against the background of the best preceding crops and yields obtained by using all the scientifically known rational soil

³D. N. Pryanishnikov. "Nitrogen in the life of plants and in Soviet agriculture." Moscow, 1945, pp. 141-142.

Table 1

Grain yield from winter rye and winter wheat without fertilizers in long-term experiments

Soils	Yields, cntr/ha
Sod-podzolic sands and sandy loams. Lyuberets experimental field, Moscow Oblast', and Novozybkov experiment station, Bryansk Oblast'	7-8
Sod-podzolic clay loams. Dolgoprud agricultural-chemical experiment station and TSKHA experiment station	12-15
Forest-steppe leached chernozems. Orlov, Sumi, and Kharkov experiment stations	15-18
Ordinary chernozem of Ukrainian steppe, Erastov experimental field, Dnepropetrovsk Oblast'	17-21
Cis-Caucasian chernozems of Don and Kuban' Rivers, Rostov and Krasnodar experiment stations	20-25

cultivation practices, planting high-quality seeds, having minimum losses during the harvest, etc.

Table 1 shows the so-called geography of the natural productivity of various soils in the European USSR. Yield data are taken from the results of long-term experiments, conducted for 15-25 years and longer under crop rotation.

The winter rye grain yield obtained was 7-8 cntr/ha on sod-podzolic sandy loams and the Novozybkov experiment station of the All-Union Institute of Fertilizers and Agricultural Soil Science (Braynsk Oblast'). This was achieved by maintaining high-level agricultural practices but without adding fertilizers (organic and mineral) to the soil.

To characterize the productivity of clay loam podzolic soils, which are more cohesive and have a higher humus content, we took the 27-year data of the Dolgoprud agricultural-chemical experiment station and the 45-year data from the Timiryazev agricultural academy. The average yield of winter rye without fertilizers on clean or clover fallow was 12-15 cntr/ha, according to these data.

The yields of winter rye and winter wheat on leached and thick chernozems of the forest steppe were 15-18 cntr/ha without fertilizers according to the 15- to 20-year data of the Orlov (formerly Shatilov), Sumi, and Khar'kov stations. On the ordinary chernozems of the Ukrainian steppe the average long-term yield of winter wheat was 17-21 cntr/ha without fertilizers (according to the data of the Erastovskiy experimental field and the Izmailovsk experiment station). Finally, in the regions of the Don and Kuban' Rivers, with rich Cis-Caucasian chernozems and favorable climatic conditions, winter wheat yields 20-25 cntr/ha of grain without fertilizers, but on well-cultivated soil.

As we can see, the winter grain yield on the naturally poor soils of the non-chernozem zone varies from 8 cntr/ha (on sandy loam and sand varieties of podzolic soils) to 13 cntr/ha (on clay loam, moderately cultivated varieties of podzolic soils) without fertilizers, but against a background of high-level agricultural practices on clean or clover fallow. The yield

of non-fertilized winter crops on late fallow and of spring grain crops are usually lower here and average 6.5 cntr/ha on sandy loams and 9-10 cntr/ha on clay loams, according to the data of the same stations in the non-chernozem belt. It must be noted that the area under spring grain in this zone is considerably greater than the area under winter crops and the winter crops are usually planted on occupied fallow and not on clean fallow.

The regions belonging to the non-chernozem belt include the Baltic republics, the BSSR, the Poles'ye of the Ukraine and the North, North-west, and Central RSFSR, the Volga-Vyatka rayon, and a considerable part of the Urals (Perm' and Sverdlovsk Oblast's and the Udmurt Autonomous Republic). The use of mineral fertilizers in this zone determines the effectiveness of all other methods of increasing soil productivity. Thus, the successful introduction of proper crop rotations depends completely on fertilizers, especially phosphorous and potassium fertilizers, as well as manure and lime on acid soils.

The experiments conducted in recent years by the Geographical Network of the All-Union Institute of Fertilizers and Agricultural Soil Science showed that the yield of all crops used in rotation, such as winter grain and spring wheat, require mineral fertilizers badly, including small amounts of nitrogen fertilizers. Clean fallow can successfully be substituted by occupied fallow in this zone by extensively using fertilizers.

The deepening of the plowed layer in podzolic soil in itself does not lead to an increase in crop yield and even lowers it, if this is done without adding manure, lime, and mineral fertilizers. The combination of deep plowing with the addition of fertilizers in layers can be expected to produce a sharp increase in crop yields.

The introduction of new selected varieties into production requires, as a rule, a high level of nutrition. This means the addition of fertilizers in the non-chernozem belt. Often many selected grain varieties give an insignificant increase in yield against a non-fertilized background and even produce less than the local old varieties.

A considerable increase in forage, necessary

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for the development of livestock at the present level of development of the non-chernozem belt, can be achieved only by using mineral fertilizers extensively for grain crops, especially corn and winter crops.

Plowland in the non-chernozem belt occupies about 25 million hectares, and land under grain crops occupies about 25 million hectares. What should be the production level of organic and mineral fertilizers in order to attain the crop yields specified by the 7-year plan? The long-term experiments of scientific institutions, the experience gained in the best kolkhozes, and the data from government crop testing stations show that 3-4 cntn/ha of mineral fertilizers and 5-6 cntn/ha of organic fertilizers are necessary for obtaining constant yields of 20-22 cntn/ha of winter grain crops, 16-18 cntn/ha of spring grain crops, 40-50 cntn/ha of hay from perennial grasses (as a result of residual effects of mineral fertilizers added to grain crops), and 200-250 cntn/ha of potatoes.

The foregoing supply of mineral fertilizers to the non-chernozem belt will correspond to the production of 31 million metric tons of mineral fertilizers, specified by the XXI meeting of the Communist Party of the USSR for the 7-year plan. As far as the supply of 5-6 metric tons of organic fertilizers per hectare is concerned, this level has already been reached in the Estonian, Latvian and Belorussian republics and in certain regions of the Ukrainian SSR and the non-chernozem belt.

Thousands of mass and long-term experiments on soils of the non-chernozem belt show that grain yields can be increased considerably in a short time by using mineral fertilizers in combination with manure and in combination with lime on acid soils. As a rule, no preliminary cultivation of these soils is needed. Let us cite several examples. In 1955 the All-Union Scientific-Research Institute of Fertilizers and Agriculture Soil Science started an experiment on a piece of land which had never been fertilized before (near the village of Mikhnevo, Moscow Oblast'), to show the effect of fertilizers in crop rotation. The soil in this area was fine-textured clay loam sod-podzolic soil, poor in nutrients and badly needing liming. The content of phosphoric acid, as determined by the Kirsanov method,

did not exceed 4-5 mg/kg of soil, and the pH of the salt extract was 4.5.

The crop yields in this experiment showed that relatively small amounts of fertilizers with moderate liming systematically increased the yield of winter wheat and clover, sown as a companion crop. The yield of winter wheat, planted in this experiment on clean, well-cultivated fallow without fertilizers, averaged only 9.1 cntn/ha of grain in 4 years (1956-1959). Clover, used as a companion crop, yielded an average of 13 cntn/ha of hay in 3 years (1957-1959). Similar yields of winter wheat and perennial grasses are obtained on such well-cultivated soils, but without fertilizers, in the kolkhozes of the Moscow and adjoining oblast's from high-quality seeds.

The addition of 3 metric tons/ha of lime (i. e., one-third of the hydrolytic acidity) to fallow increased the yield of winter wheat slightly (up to 10.8 cntn/ha). It increased the yield of clover, used as a companion crop, considerably (up to 39 cntn/ha of hay). The addition, against this background of lime, of very small amounts of granulated superphosphate as additional fertilizer (0.5 cntn/ha) during the spring planting of winter wheat and ammonium nitrate (0.6 cntn/ha), increased the wheat yield to 15.8 cntn/ha.

The addition of a combination of the same fertilizers with a base fertilizer consisting of 3 cntn of ground phosphorite and 1 cntn of potassium chloride to plowed fallow increased the grain yield of winter wheat to 20.3 cntn/ha and that of clover hay to 44.1 cntn/ha.

Thus, the addition of 5 cntn/ha of mineral fertilizers (of which 3 cntn/ha were cheap ground phosphorite) and 3 metric tons of lime to poor, non-cultivated sod-podzolic soil doubled the yield of winter wheat so that it reached the level of yields obtained on ordinary chernozems in the Ukrainian steppe.

When this combination of mineral fertilizers in the foregoing amounts was used in conjunction with 20 metric tons of semi-decomposed manure, added to plowed fallow, the average winter wheat yield in 4 years was almost 27 cntn/ha of grain, i. e., it tripled as compared to non-fertilized soil, and the yield of clover hay was

Table 2
Comparison of the amounts of fertilizer added to 1 ha of
plowed field

Years	Yield, cntn/ha			Amt. of fertilizers added to 1 ha of plowed field	
	Grain	Potatoes	Corn (green-tops)	Mineral, cntn	Manure metric tons
1960	11,8	113,0	335,4	5,0	1,8
1957-1959	4,8	53,0	89,7	1,3	1,7

Note: Comma represents decimal point.

48.9 cntr/ha, i. e., increased almost by 4 times.

The effect of mineral fertilizers was also considerable on the podzolic soils of the Novosel'sk sovkhos, Sukhinichi rayon, Kaluga Oblast'. This sovkhos, covering 12,000 ha of plowland, was given to the All-Union Institute of Fertilizers and Agricultural Soil Science in 1960 as an experimental farm to verify under production conditions the recommendations made on the use of fertilizers. The soils of the sovkhos consist mostly of exhausted podzolic clay loam and partly of gray forest soils, poor in nutrients. The yield of all crops was low. In the spring of 1960 the sovkhos was supplied with a large amount of mineral fertilizers (almost 5000 metric tons).

As a result, and in spite of very unfavorable meteorological conditions in the second part of the summer (unceasing rains), the yield of all crops increased sharply. Let us compare only the yield of grain crops (over an area of about 4000 ha), potatoes (more than 600 ha), and corn (over 200 ha) in 1960 with the yield of the same crops in the last 3 years (1957-1959) in this sovkhos (Table 2).

The yield of grain crops and potatoes more than doubled, and that of the green corn tops more than tripled. This was achieved in one year, primarily as a result of the increased amount of mineral fertilizers used.

The role of organic and mineral fertilizers in the increase in grain yields in other zones of the Union is somewhat different.

In the forest-steppe zone of the European USSR (the central regions of the RSFSR and the forest-steppes of the Ukraine) the absolute increments in grain yields, resulting from the use of manure of mineral fertilizers, are also high and partly exceed the increments on the soils of the non-chernozem belt, but the initial crop yields obtained here without fertilizers on well-cultivated soil are considerably higher. The results of long-term experiments by scientific institutions of the forest-steppe zone show that the average yield of winter grain on well-cultivated soil without fertilizers is 15-18 cntr/ha and that of spring grain, 11-12 cntr/ha. When manure and mineral fertilizers are used, and very often (on all the chernozem soils of the forest-steppe) if only phosphorous fertilizers and very small amounts of nitrogen are used, the crop yield increases sharply, reaching 22-25 cntr/ha for winter crops on fallow and 17-18 cntr/ha for spring grains.

Evidently, the effectiveness of all other progressive agricultural practices increases when fertilizers are used in the forest-steppe. Thus, the replacement of pure fallow by occupied fallow, the introduction of new selected varieties, and methods of increasing the winter resistance of winter grain in the forest-steppe are associated with the increased use of organic and mineral fertilizers. Considering that the amount of mineral fertilizers assigned to this zone for the next few years is limited, the most effective method of applying them to grain crops is the row placement of small amounts of phosphorous (and potassium) fer-

tilizers and the addition of nitrogen fertilizers as top dressing for winter grain.

The addition of granulated superphosphate during seeding, and a top dressing of nitrogen fertilizer in spring, increased the yield of grain crops (by not less than 4-5 cntr/ha) on the major soils of this zone — leached and thick chernozems. This method of adding mineral fertilizers to grain crops must be considered as the best method in the forest-steppe zone, at least in areas under winter wheat.

Corn, which gives high and consistent grain yields in most of the regions of the forest-steppe, must be supplied with organic and mineral fertilizers.

The resolutions of the January Plenum of the Central Committee of the Communist Party of the USSR (1961) call for the creation of the Soviet corn belt with the highest grain yields in the forest-steppe, as well as in the Krasnodar Province, Moldavia, and Georgia. The rapid development of corn in this belt will require considerable attention to soil fertilization.

The results of numerous long-term experiments by local scientific institutions and the experience of the leading kolkhozes and sovkhoses in the most varied regions of this zone serve as an evidence of the great effect of manure and mineral fertilizers on grain crops.

The results of long-term experiments on the thick chernozems of the Khar'kov and Sumi experiment stations, on the leached chernozems of the Orlov (formerly Shatilov) and Mironov stations, and on the podzolized chernozems and gray forest soils of the Kiev, Nosov, and Vinnitsa stations show that the addition of moderate amounts of manure (18-20 cntr/ha) to fallow increases the yield of grain from winter wheat and winter rye by 5-6 cntr/ha and ensures winter grain yield of 20-25 cntr/ha without the addition of mineral fertilizers. The residual effect of 20 metric tons of manure on the subsequent grain crops gave an additional 4-5 cntr/ha of grain. Thus, each metric ton of manure gives a total grain increment of 0-5 cntr/ha in 2-3 crops on forest-steppe soils under purely grain crop rotation. If sugar beet or any other row crop, responsive to manure, is incorporated in the crop rotation, then the consumption of manure increases and the return from 1 metric ton of manure in terms of the increment of all the crops under rotation to grain units reaches 1 cntr/ha of grain.

Phosphorous fertilizers are almost equal increments in the yield of winter grain crops on the chernozems of the forest-steppe as manure. Very often 40-50 kg of P_2O_5 in the form of superphosphate or Thomas slag, added to fallow under winter crops, gave similar increments in yield as 20 metric tons of manure, or close to it. In their residual effect on spring crops, following winter crops, phosphorous fertilizers were much inferior to manure. However, the use of phosphorous as well as nitrogen and potassium fertilizers on the thick and leached chernozems of the Forest-steppe, and especially on gray forest soils and podzolized

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chernozems, produces an increment in the yield of all the grain crops, similar to that obtained from equivalent amounts of manure.

The use of manure and mineral fertilizers has been systematically increasing in recent years in a number of kolkhozes and sovkhoses particularly in beet regions, in the forest-steppe, resulting in a steady increase in the yield of all grain crops and other important crops under rotation. Thus, the "Ukraina" kolkhoz, Gorodsk rayon, Khmel'nik Oblast', has been using more and more manure and mineral fertilizers in recent years. The yield of winter wheat at the kolkhoz, which was high before (more than 20 cntr/ha), has increased in the last 10 years by more than 7 cntr/ha and from 1955-1959 amounted to 29 cntr/ha of grain (Table 3).

In spite of unfavorable weather conditions in 1960 the amount of grain crops harvested was 36.7 cntr/ha and that of sugar beet, 350 cntr/ha. The increase in grain crop yields was accompanied by an almost 1.5-fold increase in the yield of sugar beet, the most important industrial crop. The kolkhoz harvests 52-55 cntr/ha of corn grain. The total plowland area of the kolkhoz was 2111 ha in 1959 and reached 4429 ha in 1959 after the annexation of the land of the neighboring kolkhoz. The area under winter wheat reached 1238 ha in 1959 (as against 550 ha before).

Table 3

Fertilization and yield in the "Ukraina" kolkhoz

Years	Added per 1 ha of plowed field		Yield, cntr/ha	
	Man. metric tons	Min. fertilizer, cntr.	Winter wheat	Sugar beet
1951	3,3	1,9	21,6	263
1952—1954	7,4	2,5	22,7	330
1955—1959	8,9	4,0	29,0	387

Note: Comma represents decimal point.

The fact that the steady increase in grain crop yields is related to the ever increasing use of fertilizers, especially organic fertilizers, is evidenced by the experience gained in the sovkhoses of the Kiev Sugar Trust, which cover tens of thousands of hectares. The amount of organic fertilizers used in the beet-growing sovkhoses of this Trust, which are located in the Kiev and Chernigov Oblast's, has more than doubled in the last 15 years. The use of mineral fertilizers, added primarily to sugar beets under crop rotation, has also increased 1.5 times in these kolkhozes. A top dressing of nitrogen was used in spring on winter wheat. Table 4 shows the increase in the use of fertilizers and the dynamics of grain crop yields at 16 beet-growing sovkhoses of this Trust.⁴

Thus, in the last 5 years the average yield of all grain crops over an area of 68,000 ha has reached almost 20 cntr/ha of grain, while that of winter wheat (which is usually better fertilized) has reached 25 cntr/ha of grain over an area of 14,600 ha.

As we can see, the average consumption of fertilizers per hectare of plowed land in the beet-growing sovkhos was relatively small in these 5 years. This amount is fully adequate for the next few years for the mass production of sovkhoses and kolkhozes in the forest-steppe regions of the Ukraine.

Because of frequent droughts grain crop yields are irregular in the steppe regions of European USSR (Ukraine, Northern Caucasus, the Volga region) and in the main regions of Kazakhstan and Siberia. The average grain yield (after previous crops) in a number of regions in this zone is lower than the yield in the forest-steppe. This lowers the average crop yield of the Union because of the large areas under crops. The most important factor in these regions is the rational cultivation of soil, directed toward maximum moisture conservation and accumulation and proper crop rotations, which rids the fields of weeds.

⁴ The data used were analyzed by the agronomist of the Kiev Sugar Trust, V. T. Svyatelik, and kindly given to us.

Table 4

Fertilizers and yield in beet-growing sovkhoses of the Kiev Sugar Trust

Years	Fertilizers added to 1 ha of plowed field		Grain yield, cntr/ha		Area under crop, thousands of ha	
	Organic, metric tons	Mineral, cntr	All grain crops	Winter wheat	All grain crops	Winter wheat
1946—1950	1,8	1,4	13,8	14,9	58,0	13,2
1952—1955	3,4	2,0	16,3	16,3	58,0	22,2
1956—1960	4,2	2,3	19,9	25,1	68,1	14,6

Note: Comma represents decimal point.

Of no lesser importance in the increase of the resistance of grain crops (first of all, spring and winter wheat) to the severe climatic conditions in the entire steppe zone of the European and Asiatic USSR, in addition to the complete utilization of manure, is the extensive use of small amounts of granulated superphosphate in rows during seeding of wheat. This method of fertilizer placement over wide areas is the most economical way of increasing grain production in this zone. Larger amounts of mineral fertilizers, including nitrogen fertilizers, together with the full utilization of manure, are of great importance for increasing corn and wheat yield in the irrigated areas of our steppe regions.

All the experiments conducted with organic and mineral fertilizers under irrigated conditions in the Kuybyshev, Saratov, Stalingrad, Kerson, Zaporozh'ye, and Crimea Oblast's, and in the Krasnodar and Stavropol' provinces serve as evidence of the sharp increase in the effectiveness of irrigation when combined with the use of fertilizers. If without fertilizers the wheat yield on well-cultivated soil, using the proper system of irrigation, averages 20 ctnr/ha then this yield can be easily increased to 30-35 ctnr/ha by the rational use of fertilizers.

Each kolkhoz and sovkhoz of the country must

be concerned daily with the preparation and utilization of local fertilizers. The main problem is that of proper work organization and the mechanization of the preparation of fertilizers and their transportation of the fields.

The extensive use of mineral fertilizers for grain crops is often limited by economic considerations. The opinion still prevails that because of their cost and the cost of storage of agricultural products it is only economical to use mineral fertilizers for industrial and subtropical crops and that their use for grain crops is not profitable. Is it so? Calculations show that under certain conditions it is profitable to use mineral fertilizers for grain crops, sometimes even more profitable than for industrial crops.

Table 5 shows the results of calculations made by the economists of the All-Union Scientific-Research Institute of Fertilizers and Agricultural Soil Science on the economic effectiveness of mineral fertilizers used under various conditions for grain crops as compared to their use for the major industrial crops. In evaluating the economic effectiveness of mineral fertilizers two important criteria were used: the magnitude of the pure profit from the use of fertilizers per hectare of planted area and the level of return on investment.

Table 5

Economic effectiveness of the use of mineral fertilizers for grain crops

Methods of fertilizer placement and crops	Average yield increment, ctnr/ha	Pure profit, ruble per ha	Return on investment, % (ratio of pure profit to expenditures)
Complete mineral fertilizer (NPK) at a rate of 40-60 kg of nutrients for winter or spring wheat in the non-chernozem belt	8	34	131
Row placement of 0.5 ctnr/ha of granulated superphosphate under winter wheat in the non-chernozem belt and in the forest-steppe	2,5	16,6	690
Early-spring top dressing of winter wheat with nitrogen fertilizer at a rate of 20 kg N	3	16,1	242
Addition of 3 ctnr/ha of ground rock phosphate to podzolic soils and leached chernozems under winter crops	3	15,1	195
Row placement of 0.5 ctnr/ha of granulated superphosphate under spring wheat in steppe reg.	1,5	9,0	380
Complete mineral fertilizer under corn in the steppe	6	22,0	100
Complete mineral fertilizer for corn (silage)	120	73	264
Complete mineral fertilizer under flax on podzolic soils	1,5	27,1	348
Complete mineral fertilizer under sugar beet on leached chernozems of Ukrainian SSR	70	82	99
Nitrogen-phosphorous fertilizers under cotton on sierozems of Uzbek SSR	10	215	175
Complete mineral fertilizer under potatoes on podzolic soils	60	162	257

Note: Comma represents decimal point.

The first value was determined from the difference between the cost of the increment of the marketable part of the yield in sales prices and the sum of all the expenses of a farm when using mineral fertilizers, as reduced to 1 ha. The return on investment was determined as the ratio between the pure profit from fertilizers and the cost of their use per hectare of planted area.

In spite of a certain conditionality of these calculations, made on the basis of averaged data, we can see the relative effectiveness of the use of mineral fertilizers for individual crops and, especially, the relative effectiveness of various methods of using mineral fertilizers for one and the same crop. As we can see from these data, the use of mineral fertilizers increases the return from the hectare even for grain crops.

Profits are undoubtedly higher from industrial crops (as well as from such food crops as potatoes in the non-chernozem belt) than from grain crops and not as much because of their greater response to fertilizers, but primarily because of their higher selling prices. However, even though the pure profit from grain crops per hectare as a result of mineral fertilizers is smaller than that from industrial crops, they exceed many of the latter in the level of return on investment in mineral fertilizers. For instance, all the recommended methods of mineral fertilizer application to grain crops give a somewhat higher return than the accepted system of sugar beet fertilization. If, however, we use the most modern methods of mineral fertilizer placement, we can reach a level of return which cannot be reached by the common system of fertilizer application to industrial crops. Thus, the row placement of small amounts of granulated superphosphate under spring wheat in the steppe regions ensures a return on investment of 380%, the return from each ruble spent is 3 rubles and 80 kopeks, while the same method of superphosphate placement under winter wheat ensures a return on investment of 690%, i.e., the profit from each ruble spent is 6 rubles and 90 kopeks.

Such a high return on investment in mineral fertilizers is not even obtained from the use of these fertilizers for flax, which is the most profitable of the industrial crops. The return on investment in mineral fertilizers in amounts used for flax on podzolic soils (and against a background of clover) is 348%.

Thus, of all the accepted methods of adding mineral fertilizers, the row placement of small amounts of granulated superphosphate under grain crops is the most profitable.

This method of fertilizer placement is comparatively new (since granulated superphosphate has been produced only since 1950), but because of its high return it has been rapidly introduced into production and shows a tendency of becoming the most widely accepted method. A rather high return is obtained from a top dressing of winter grain crops with nitrogen. The return from this method is 242%.

The use of sufficient amounts of a complete fertilizer as a basic fertilizer for grain crops in regions of the non-chernozem belt ensures a return on investment of 131%, which is slightly

lower than the return from cotton on irrigated sierozems in Central Asia and higher than the return from fertilizers used in accepted amounts for sugar beet on the chernozems of the Ukraine.

The fulfillment of the foregoing plan of the use of 10 million metric tons of mineral fertilizers (including 3 million metric tons of nitrogen fertilizers) for grain crops by the end of the 7-year plan will ensure an increase in the annual production of grain crops of at least 20 million metric tons, i.e., more than a billion poods. Such an increase (because of mineral fertilizers) will raise the average grain production by 1.1 cntr/ha and considerably more in areas better supplied with fertilizers, as compared to the present level. For instance, by using mineral fertilizers the average crop yield in Latvia, Estonia, and Lithuania can be increased by 5-6 cntr/ha and that in the central regions of the non-chernozem belt of the RSFSR and the BSSR, by 3.5-4 cntr/ha.

We established the possible increase in grain production on the basis of very conservative calculations of the effectiveness of mineral fertilizers on grain crops. In our calculations each metric ton of mineral fertilizers ensures an average grain increment of 2 metric tons. Actually, one ton of mineral fertilizers gives an increase of 3-4 metric tons of grain in most of the cases. Moreover, we took into consideration only the direct effect of mineral fertilizers, which are placed directly under grain crops.

Actually, the so-called residual effect of mineral fertilizers would play an important role in the increase in grain production. In this respect we must consider not only the residual effect of fertilizers, added to grain crops during crop rotation, but also the residual effect of tremendous amounts of mineral fertilizers (more than 15 million metric tons) at the end of the 7-year plan, which will be added to industrial crops, potatoes, and forage crops under rotation, which usually include fields with grain crops.

It is very important for the grain economy that the production of granulated superphosphate and ground phosphorite be increased in the next few years of the 7-year plan. The supply of nitrogen fertilizers for corn and for the top dressing of winter crops in the non-chernozem belt and the forest-steppe also must be increased.

There is little progress in this respect. Thus, not enough granulated superphosphate, which is especially important in the grain economy, is produced by our superphosphate plants. The output of special, combined spreaders for placing granulated fertilizers under grain crops and corn must be sufficient. The production of ground phosphorite, used primarily for grain crops, does not satisfy its demand. The problem of the increase in grain production cannot be solved without mineral fertilizers.

It is evident that the total increase in grain production as a result of mineral fertilizers will be considerable by the end of the 7-year plan. It is also clear that efforts are needed to realize the foregoing plans and for the chemical industry to fulfill the resolutions of the XXI meeting of the Communist Party of the USSR and of the January Plenum of the Central Committee of the Communist Party of the USSR with respect to the increase in the production of mineral fertilizers.

ESTABLISHMENT OF THE FUTURE REQUIREMENT OF AGRICULTURE FOR FERTILIZERS

A. V. SOKOLOV

Because of the studies by scientific-research institutes and agricultural experimental stations we now possess data on the effectiveness of fertilizers on the major agricultural crops in principal USSR soil groups. This information makes it possible to calculate approximately the future requirements of agriculture in mineral fertilizers. The accuracy of planning requirements in fertilizers depends first of all on the reliability of information about the types of crops grown on given soils, and, secondly, on the proper use of experimental data on the effect of fertilizers on various soils.

To obtain a general idea of the requirement of Soviet agriculture for fertilizers, we can use the results of the quantitative assessment of the soil resources of the USSR, begun by Academician L. L. Prasolov and continued at the V. V. Dokuchayev Soil Institute under the supervision of N. N. Rosov. But for more accurate calculations of the requirement for fertilizers we must have information on the distribution of areas under fertilized crops by soil groups and species. Up to this time such calculations were only tentative and based on small-scale general soil maps. Therefore, at present only a few necessary quantitative indices have been established to calculate the requirement of agriculture for fertilizers. For instance, we did not even have data on the extent of the area fertilized with phosphorite. It is generally known that ground phosphorite is used directly as a fertilizer on acid podzolic and sod-podzolic soils, as well as on gray forest soils, and podzolized (degraded) and leached chernozems. When planning requirements for ground phosphorite, all plantings in the non-chernozem belt and those in a number of regions in the chernozem zone, in which ground phosphorite is effective, were included in the zone of applying phosphorite to soil. But there are non-acid sod-calcareous soils in the non-chernozem belt, as well as limed soils. In the chernozem belt, however, the boundary between leached and non-leached chernozem is very diffuse, and these soils shift now to the south, now to the north. Recently for the first time, the Phosphorus Laboratory of the Scientific Institute of Fertilizers and Insecticides (V. F. Kalganova) in collaboration with the Geography Department of the V. V. Dokuchayev Soil Institute, calculated the areas under crops which require phosphorite. In European USSR these areas proved to cover about 54 million hectares. But if soil

liming is really put into practice, the area subject to application of phosphorus will be reduced by half, to about 28 million hectares. This will change the importance of the non-chernozem belt considerably, as far as the consumption of ground phosphorite is concerned, since we all know that in countries where mass liming is practiced, very little ground phosphorite is used. After the non-chernozem belt of the USSR is limed, ground phosphorite will be used primarily for transitional soils (gray forest soils, and podzolized and leached chernozems), while in the sod-podzolic soil zone ground phosphorite will be used primarily for improving newly-reclaimed virgin lands.

Let us cite another example, which shows how important a detailed knowledge on what crops are grown on what soils is for the future planning of the production of fertilizers. Magnesium fertilizers are very important for sod-podzolic sandy and sandy soils, especially in areas where potatoes are grown. Approximately equally large areas with sandy soils in the western and eastern parts of the non-chernozem belts of the European USSR, and relatively smaller areas in its central part, require different amounts of fertilizers containing magnesium. The assessment of soils used under crops and forests (superposition of soil contours on the contours of forest maps) showed that there are 10 times more areas with coarse-textured soils under crops in the western regions and 2 times more in the central regions than in the eastern regions. The total amount of sod-podzolic coarse-textured soils under crops proved to be 30% more than expected earlier.

Thus, the first stage in the planning of the production and use of fertilizers in the future must be the gathering of more detailed data on the distribution of crops on various soils. The content of nutrients available to plants in the soils is not the same throughout fields occupied by a given soil variety. The history of the agricultural utilization of fields and natural conditions, which create various degrees of fertility (and are not fully accounted for during soil mapping), are of essential importance for the improvement of soil fertility. The establishment of genetic soil species is of great importance in the work of the agronomist and agricultural chemist, but it must be supplemented by soil analysis for available nitrogen, phosphorus,

potassium, and other elements.

Countries which use a large amount of mineral fertilizers make detailed agricultural-chemical soil maps in order to determine the requirement of agriculture for fertilizers. This is not done yet in the USSR. Fertilizers are used without properly taking into account their requirement by the fields, only on the basis of the effectiveness of fertilizers on one or the other soil. Certain republics construct large-scale soil maps of sovkhozes and kol-khozes, but do not accompany them with the necessary agricultural-chemical soil studies, and therefore cannot sufficiently improve the practical use of fertilizers, nor contribute to our knowledge of the requirement of Soviet agriculture for fertilizers. The agricultural-chemical soil mapping, conducted on certain farms for experimental-methodological purposes, showed that not less than one-third of the fertilizers is now being wasted or is little effective.

The average indices of the effectiveness of fertilizers, obtained experimentally, are used in determining the requirement of various crops for fertilizers. These indices give an erroneous idea of the future effectiveness of fertilizers when they will be used in conformity with local conditions. The requirements for fertilizers, calculated on the basis of average indices, are too high, since they are designed for the even distribution of fertilizers over the entire planted area, and are not differentiated on the basis of soil analyses.

Increased crop yields are obtained not only from the addition of fertilizers, but by improving soil tillage, planting more productive crop varieties, introducing crop rotation, etc. The addition of mineral fertilizers is very important, but is not the only means of increasing crop yields. Improved soil tillage, the introduction of new crop varieties, the use of herbicides, and other agricultural measures cannot be considered only as conditions for the effective use of fertilizers. In a number of regions a change in agricultural practices and the introduction of new crop varieties have their own individual importance in the increase in crop yield, since they increase the utilization of natural resources.

Thus, the accuracy of the determination of the requirement of agriculture for mineral fertilizers is reduced as a result of the lack of agricultural-chemical soil maps, the use in the calculations of average indices of the effectiveness of fertilizers, and insufficient information on the quantitative participation of agriculture practices and selection in the increase in crop yield. All this leads to the planning of fertilizer requirements which are too high.

According to statistical data, the increase in the production of nitrogen fertilizers is greater than that of phosphorous fertilizers. This cannot be considered as accidental, it is entirely regular and substantiated scientifically. Our studies by means of the radioactive phosphorus isotope showed that the old ideas of the extremely low utilization coefficient of phosphorous fertilizers and of the

retrogradation in the soil of soluble phosphates into forms not available to plants are incorrect. The new theoretical positions on the utilization of phosphorous fertilizers, on their transformations in soils, and on the supply of available phosphates in soils agree with the established fact of the prolonged residual effect, which lasts for many years, of all forms of soluble phosphates in all soil species. The addition of phosphates (in amounts recommended now) has led to the overfertilization of soils with phosphorus in a number of areas in Central Asia and in regions where beets are grown, i.e., where fertilizers were used intensively. Therefore, the amounts of phosphorous fertilizers used in such regions will be gradually diminished.

The use of nitrogen fertilizers increases as compared to phosphorous fertilizers because the removal of nitrogen by plants is about 3 times higher than that of phosphorus (P_2O_5) and because nitrogen fertilizers do not have a prolonged residual effect. Sod-podzolic and podzolic soils require nitrogen fertilizers badly. If in 1959 the ratio between nitrogen, phosphorous, and potassium fertilizers in the total production of fertilizers was 1:1.7:0.5 (in standard units), then in the future it will probably change to 1:0.7:0.9. It must also be considered that phosphorous deposits are limited and the mining of agricultural ores becomes more and more difficult, whereas the possibilities of synthesizing nitrogen compounds are unlimited.

Another feature of the future production of mineral fertilizers must be the increase in the assortment of fertilizers and the improvement of their quality, in particular their physical properties, their storability, transportability, and ease of application, as well as an increased concentration of nutrients in the fertilizers. Fertilizers must include not only those containing nitrogen, phosphorus, and potassium, but also such microelements as magnesium, sodium, sulfur, and calcium.

The use of compound and mixed fertilizers increases, but simple fertilizers will also be used in large amounts as before. Thus, the use of fertilizers will sharply increase in the USSR. At the present time they are used intensively only in a number of West European countries and in Japan. Large amounts of fertilizers are also used in the U.S.A., but their amount per hectare of plowed field is small as a result of the large areas under crops. In the USSR fertilizers are intensively used in irrigated areas and on industrial crops, such as sugar beet, tobacco, tea, etc. The experience of West European countries cannot be mechanically transposed to the USSR, since the areas under crops in those countries are insignificantly small, population is dense, grain and forage crops are imported, and the soils are poor in the zone of adequate moisture. Therefore, the experience gained in West European countries, relative to the amounts of fertilizers to be used and their application can be used primarily for planning the utilization of fertilizers in the piedmont areas of the non-chernozem belt. When using indices of the amount of fertilizers per hectare we must remember that these data do not correspond to the real application of fertilizers in plowed areas. Meadows and pastures, which occupy

areas as extensive as the area of plowed fields, are also being intensively fertilized in a number of countries. The amount of fertilizers actually used per hectare of plowed field is much smaller than that calculated by dividing the total amount of fertilizers used by the area occupied by plow-land.

The U. S. A. uses up to 28-30 million metric tons of standard mineral fertilizers. As a result of this, crop yield increased 1.5-2 times. The U. S. A. exports about one-third of its wheat, one-fourth of its cotton, and other agricultural products. Since 1953 a compulsory reduction of the production of wheat, corn, rice, cotton, and other crops has been introduced in the U. S. A. The area under these crops has been reduced by 12.4 million hectares from 1953 to 1958, while the production of all the major crops has increased greatly, except for cotton, the production of which has decreased by 31.4% in the last 5 years, which is understandable since cotton is being replaced by synthetic fibers.

Considering that the area under crops in the U. S. A. occupies about 135 million hectares, and that of the USSR, about 200 million hectares, we may assume on the basis of the experience gained in the U. S. A. that 45 million metric tons of standard mineral fertilizers would increase the crop yield in the USSR 1.5-2 times. A tremendous amount of grain is produced in the USSR by virgin lands with fertile soils in dry regions.

The production of 45 million metric tons of fertilizers will make it possible to use about 0.5 metric tons of standard mineral fertilizer (120 kg of nutrients) per hectare in the zone where fertilizers are highly effective, i. e., use mineral fertilizers extensively in the zone with adequate soil moisture. A further increase in crop yield will probably require a larger amount of fertilizers.

At the present time grain is primarily produced in the zone where fertilizers are relatively little effective. The production of high average grain yields in the non-chernozem and in the forest-steppe zones will require the use of large amounts of fertilizers.

The most productive of all grain crops are winter wheat and corn in regions with favorable climatic conditions. The average yield of winter wheat has reached 15-16 ctnr per ha in recent years. In planning grain production, the yield of winter wheat could be increased to 25 ctnr per ha. Such high yields are obtained in the non-chernozem zone when manure, lime, phosphorite, and relatively small amounts of mineral fertilizers are used. The average winter crop yield in the chernozem zone of certain parts of the Ukraine and the RSFSR was 20-27 ctnr of grain per ha in 1958 and 1959. Therefore, an average winter crop yield of 25 ctnr per ha must be considered as entirely possible with small expenditures of fertilizers. But high grain yields (about 30 ctnr per ha) are entirely possible if winter-crop non-lodging varieties are sown in the zone of adequate moisture and the necessary amount of mineral fertilizers is used against a background of manure, lime, and phosphorite.

Another productive grain crop is corn. High corn yields may be obtained by sowing highly productive hybrid corn varieties on well-prepared soil, by destroying weeds with specific herbicides, and by adding mineral fertilizers together with manure and other local fertilizers. But this will be possible only when corn plantations in the zone of adequate moisture are supplied with a large amount of mineral fertilizers, mostly nitrogen.

At the present time average spring crop yields reach 9-10 ctnr per acre. An increase in their yield may be obtained in the beginning primarily from the residual effect of fertilizers, the use of herbicides, improved soil tillage and the elimination of losses during the harvest, and the row placement of granulated superphosphate and certain amounts of nitrogen and potassium in the zone where fertilizers are effective. A further increase in the yield of spring crops will require large amounts of nitrogen fertilizers in the zone of adequate moisture.

The problem of obtaining large amounts of forage crop is more complicated. At the present time the USSR has little cultivated meadows and pastures. It is difficult to say how many can be planned. If the area under crops will be increased at the expense of meadows and pastures, the best of these will be used, and, consequently, it will be very difficult to create cultivated meadows. Approximately the same amount of fertilizers as is now being used for industrial crops will be needed in the zone of adequate moisture to fertilize cultivated meadows and pastures in order to obtain high yields. Nitrogen fertilizers are most important for the fertilization of hay fields and pastures. Large amounts of nitrogen fertilizers must also be used for ensilage crops, since they include corn for ensilage and green forage.

The use of a large amount of mineral fertilizers requires a number of conditions without which they are insufficiently effective and economical.

1. An agricultural-chemical soil service (local and regional agricultural-chemical laboratories) must be established, and the agricultural-chemical mapping of soils must be completed by 1965.
2. All acid soils of the non-chernozem belts must be completely limed by 1965.
3. The assortment of fertilizers, their packing, transportation, storage, and application must correspond to the high level of the use of fertilizers. The construction of mineral fertilizer spreaders, storehouses, mixers, and the delivery of packed fertilizers must be provided for.
4. All fields under grain crops must be freed of weeds by proper tillage methods and the use of herbicides in spring.
5. Agriculture must be supplied with highly productive plant varieties, in particular non-lodging varieties of grain crops.

FUTURE FERTILIZER REQUIREMENTS

6. The use of organic and other local fertilizers, first of all that of manure, must be increased by developing animal husbandry and other measures.

7. To ensure the scientific solution of problems of plant nutrition and the use of fertilizers an All-Union Institute of Agricultural-Chemistry must be organized, as well as agricultural-chemistry institutes in all the Soviet republics. Departments of agricultural chemistry must be reestablished in agricultural institutes and experiment stations.

When the agricultural-chemical mapping of soils is completed, the agricultural-chemical service established, agricultural-chemical institutes and laboratories organized, and the application of mineral fertilizers based on the actual requirement of every agricultural field for nitrogen, phosphorus, and potassium (and new progressive methods of fertilizer application are used), then the effectiveness of fertilizers will increase sharply. This in its turn will lead to a decrease in capital investment and not less than double the income of the national economy from the production and use of fertilizer.

COMPARATIVE EVALUATION OF MODERN COMPOUND FERTILIZERS AND EQUIVALENT MIXTURES OF SIMPLE FERTILIZERS

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The resolution of the Central Committee of the Communist Party of the USSR and the Council of Ministers of the USSR calls for the production of 9 million metric tons of mixed and compound fertilizers in 1965, including 1.4 million metric tons of compound fertilizers. As we know, compound fertilizers in agricultural practice are fertilizers containing several elements necessary to plants in every granule. Double (nitrogen and phosphorus) and triple (nitrogen, phosphorus, and potassium) compound fertilizers are produced. The combination of several nutrients in one fertilizer is of physiological and economical importance. The absorption by the roots of ions required by plants from the soil is accompanied by an expenditure of energy. Therefore it is only natural that the better the nutrients are distributed in the soil, the more completely and easily they are taken up by agricultural crops, and the less energy is lost by the latter, which is supplied by oxidation processes (including respiration). As far as the economical advantages of compound fertilizers are concerned they include reduced costs of packaging, storage, and transportation, which is especially important in such a large country as the Soviet Union. Moreover, there is no need of preparing mixtures from simple fertilizers in each farm, which is very costly. It is sufficient to say that 1 metric ton of compound fertilizer, containing 16.8% nitrogen, 12% phosphorus (P_2O_5), and 13.5% potassium (K_2O)¹ replaces 510 kg of ammonium nitrate (33% N), 649 kg of superphosphate (18.7% P_2O_5), and 380 kg of potassium chloride (52% K_2O), or a total of 1.53 metric tons of these valuable simple fertilizers.

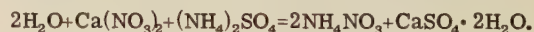
Methods of Production

The production of solid compound fertilizers is based on the breaking down of phosphatic raw material (apatite or phosphorite) by means of nitric acid. This method was first suggested by D. N. Pryanishnikov in 1908, but was put into practice much later (since 1956 in the USSR) because of technical difficulties. The advantage of this method, as compared to the most common method of using sulfuric acid (during

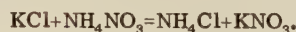
the manufacture of simple superphosphate), is that nitric acid decomposition gives two fertilizers simultaneously — a phosphorous (a precipitate consisting partly of superphosphate and H_3PO_4) and a nitrogen (calcium nitrate) fertilizer.

The mixture obtained has poor physical properties because of the hygroscopicity of calcium nitrate and is not used as a fertilizer without further treatment. There are 6 methods of treating it and all have the same purpose, that of transferring calcium nitrate into other compounds.

1. Ammonium sulfate is added to the mixture (pulp) when it is still hot and paste-like (to facilitate the interaction). The ammonium sulfate reacts with the calcium nitrate and ammonium nitrate and calcium sulfate (gypsum) are formed:



If a triple fertilizer is required, an appropriate amount of potassium chloride is added to the reacting hot mass (pulp) during the same stage of the process. It interacts partly with ammonium nitrate, forming ammonium chloride and potassium nitrate:



Later the mass is dried and granulated to the desired size. Each granule contains $CaHOP_4 \cdot 2H_2O$, $Ca(H_2PO_4)_2 \cdot H_2O$, NH_4NO_3 , NH_4Cl , KCl , KNO_3 , $CaSO_4 \cdot 2H_2O$ and those impurities which were contained in the initial phosphatic raw material. This fertilizer is called sulfatic nitrophoska, has good physical properties, and may be used in various ways, including pre-planting application.

2. In a similar manner, by adding potassium sulfate to the mixture after the decomposition of the phosphatic raw material with nitric acid (pulp), calcium nitrate may be changed to potassium nitrate and gypsum and a triple fertilizer is obtained. However, this method is not commonly used because of the high price of potassium sulfate. Potassium sulfate can be replaced by sodium sulfate and then gypsum and sodium nitrate are obtained. To obtain a triple fertilizer we must add potassium chloride to the pulp.

¹As an example take a sample of nitrophoska, a compound fertilizer produced in the USSR at the Dneprodzerzhinsk Artificial Nitrogen Plant.

3. When adding ammonia and sulfuric acid to the pulp the same result is obtained as when ammonium sulfate is added. But, as practice has shown, ammonia can produce a partial retrogradation of the available phosphoric acid salts (i. e., their transformation into less available compounds) as a result of the local leaching. To avoid this, a small amount of soluble magnesium salt is added at the same time. The addition of potassium chloride produces a fertilizer which is similar in composition and properties to sulfatic nitrophoska, and which is called sulfuric nitrophoska.

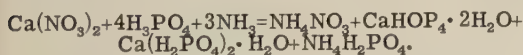
It must be noted that the use of the expensive sulfuric acid increases the cost of production of nitrophoska. One of the advantages of the nitric acid decomposition of phosphatic raw material is the reduced need or no need at all in sulfuric acid. Nitric acid is obtained from the oxidation of ammonia, synthesized from atmospheric nitrogen. Plants for the manufacture of compound fertilizers must therefore be located near artificial nitrogen plants and supply them with apatite and potassium chloride.

It must also be noted, however, that less sulfuric acid is needed (about 1 kg) for the production of 1 kg of P_2O_5 in sulfuric nitrophoska than for the production of the same amount of P_2O_5 in superphosphate (up to 2.5 kg of H_2SO_4).

4. Calcium nitrate can be removed from the pulp by crystallization on cooling. Ammonia, sulfuric acid, magnesium salt, and potassium chloride are added to the remaining mass (soluble phosphates and partly $Ca(NO_3)_2$). The so-called frozen-out nitrophoska is obtained, while the separated calcium nitrate is granulated and used as a nitrogen fertilizer.

In this method the consumption of sulfuric acid is considerably smaller than in the production of sulfuric nitrophoska, but the consumption of energy increases for cooling the pulp to remove calcium nitrate. Later the rest of the pulp must be warmed again.

5. A very promising method is that of adding ammonia and phosphoric acid to the pulp. In doing this, calcium nitrate changes into mono- and di-substituted calcium phosphates and ammonium nitrate, moreover, ammophos is produced:



The addition of potassium chloride gives NH_4Cl and KNO_3 also. The soluble calcium phosphates and impurities contained in the phosphatic raw material, which are in the pulp, form part of the fertilizer obtained.

A method of producing phosphoric acid by the thermal reduction of low-percentage phosphorites and subsequent oxidation of the elementary phosphorus into phosphoric acid is being developed at present. The phosphoric acid obtained can be used to produce nitrophoska by the foregoing method.

6. The least expensive method of producing nitrophoska is by treating the hot pulp (the

mass obtained from the decomposition of phosphatic raw material by nitric acid) with ammonia and carbonic acid. In doing this, calcium nitrate changes to ammonium nitrate and calcium carbonate. In order to prevent the retrogradation of phosphates, a small amount of magnesium salt is added. In order to obtain a triple fertilizer, potassium chloride is also added to the pulp. In the end this nitrophoska, called carbonate nitrophoska, contains $CaHPO_4 \cdot 2H_2O$, NH_4NO_3 , NH_4Cl , KNO_3 , KCl , $CaCO_3$, and impurities.

Since carbonate nitrophoska contains no water-soluble phosphoric acid salts, it should not be granulated. The precipitate is more easily taken up by the plants in close interaction with the soil, which is interfered with by the granules. However, carbonate nitrophoska in powder form may deteriorate in storage. Its physical properties must be improved.

The reason for the relatively low cost of this nitrophoska is that the carbonic acid used for binding calcium is a waste product of the synthesis of ammonia when methane is used. In its turn less expensive ammonia is produced from atmospheric nitrogen on the basis of methane.

In recent years the U. S. A. and England have begun mass producing liquid compound fertilizers. Liquid phosphoric acid is neutralized with liquid ammonia and potassium chloride is added to the solution obtained. Such a triple fertilizer must also find application in our country.

Influence of Triple Fertilizer Compounds on the Yield and Quality of Agricultural Crops

Since the solubility of nitrogenous and potassium components in compound and simple fertilizers is approximately the same (while phosphates in all the nitrophoskas are less soluble than in superphosphate), in comparing the effectiveness of compound and simple fertilizers we must consider first of all the availability of phosphates to plants.

Since 1957 we have conducted a series of greenhouse and field studies on the comparative effect of various nitrophoskas on the yield and composition of plants. As control we used mixtures of equivalent nutritional value of simple fertilizers most commonly used in the USSR: granulated ammonium nitrate (Na), granulated superphosphate (Ps), and potassium chloride (Kc). In the present paper we will discuss primarily the results of field experiments conducted in the sovkhoses and kolkhozes of the Moscow Oblast' on sod-podzolic clay loam soils of various degrees of cultivation.

Experiments with potatoes. Granulated nitrophoskas are most conveniently applied to potatoes with square-hill planters (SKG-4) together with the tubers. To verify this method we conducted preliminary experiments by applying compound fertilizers by hand while planting the potatoes (Lorch). The results of these experiments are presented in Tables 1, 2, 4-6.

The first experiment was made in 1958 in the "Ogorodnyy gigant" kolkhoz, Moscow Oblast', on cultivated soil (pH of the salt extract — 6.4; v, 99%, humus, 4.5%).

As we can see from Table 1, the effect of sulfuric nitrophoska on the yield of potatoes and their quality (starch content) was considerably greater than that of the mixing of simple fertilizers.

Sample tubers from various experiment treatments were placed in a cellar for storage 180 days after the potato harvest and analyzed for their content in starch, total nitrogen, protein, ascorbic acid, and 2 ash elements, phosphorus and potassium. The results of the analyses are summarized in Table 2. Cultivations showed that the average daily loss in starch (by respiration and other oxidation processes) was: 0.022% for the control (non-fertilized), 0.023% with NPK, and 0.022% with nitrophoska. Consequently, there is no substantial difference between these treatments.

Starch was determined by acid hydrolysis; total nitrogen, by the Kjeldahl method; protein, by the Barnshteyn method; phosphorus was determined colorimetrically by the Deniège method as modified by Maluginina and Khrenova (after wet ashing by the Lebedyantsev method); potassium, by the Tananayev method (in the form of the complex potassium-silver-cobalt nitrite salt after dry ashing); and ascorbic acid, by titration with 2, 6-dichlorophenolindophenol.

As we can see from Table 2, potatoes grown on hill-placed mineral fertilizers were better in almost all their qualitative indices than those grown without fertilizer, whereby nitrophoska was superior than the mixture of simple fertilizers. Tubers from the control contained only somewhat more ascorbic acid.

The uptake by the potatoes of nitrogen, phosphates, and potassium from nitrophoska was more intense than from an equivalent mixture of simple fertilizers. The removal of these substances was naturally much higher from the

Table 1

Comparative effect of sulfuric nitrophoska and a mixture of simple fertilizers on potatoes in the "Ogorodnyy gigant" kolkhoz (average of 3 replicates)

Experimental treatment (amounts of nitrogen, available P_2O_5 and K_2O , kg/ha)	Yield and increment in tubers, %	Starch content, %	Yield and increment in starch, cntr/ha
Without fertilizer	131,1 ^a	15,8	20,7
Sulfuric nitrophoska No. 72 ^b 25-22-27.8	+42,8	16,3	+7,6
NPK 25-22.6-27.8	+24,4	15,6	+3,6

^aThe accuracy coefficient of the experiment, calculated by the Peregodov method is 0.23%. The differences in yield between the treatments are completely reliable.

^bThe nutrient content in this nitrophoska is: 16.4% nitrogen, 14.4% available P_2O_5 , and 17.4% K_2O ; available P_2O_5 contains 3.6% water-soluble P_2O_5 .

Note: Comma represents decimal point.

Table 2

Composition of potato tubers after 6 months of storage, %

Experimental treatment	Dry substance	Starch	Total nitrogen	Protein	P_2O_5	K_2O	Ascorbic acid, mg %	Daily losses of starch, %
Without fertilizer	22,06	11,78	0,61	1,7	0,43	0,71	13,0	0,022
Sulfuric nitrophoska	28,06	12,30	0,74	1,85	0,52	1,01	11,0	0,022
NPK	23,54	11,40	0,66	1,80	0,46	0,95	10,8	0,023

Note: Comma represents decimal point.

COMPOUND AND SIMPLE FERTILIZERS

fertilized treatments, especially from nitrophoska, since it produced a higher yield.

The next experiment was made in 1959 in the training sovkhos "Dubki" with 3 nitrophoskas; the amounts of nutrients were adjusted according to the content of available phosphates; the amounts of N and K_2O falling short were added in the form of simple salts (in Table 3 these additions are indicated by a plus sign). The soil was moderately podzolic medium clay loam (pH of the salt extract, 4.3; available aluminum, 1.64 meq/100 g).

As we can see from Table 3, the plant requirement for phosphates was pronounced. The greatest increment in yield was obtained from Italian nitrophoska, which contained the maximum amount of water-soluble phosphates. The yield increments are reliable (except for the NK treatment). The maximum nitrogen content in the tubers was obtained from the frozen-out nitrophoska. The phosphorus and potassium content was highest in the control tubers, since a considerable yield increment was obtained even with insignificant amounts of fertilizers.

The same year we conducted another experiment in the sovkhos "Dubki." We added various nitrophoskas and an equivalent mixture of simple fertilizers to the hills while planting the potatoes (Berlichigen). The amounts used were 20 kg/ha of available P_2O_5 , 30 kg/ha of nitrogen; and the Italian nitrophoska was supplemented (to equalize the amount of nitrogen) with ammonium nitrate. The results of the experiments are summarized in Table 4.

As we can see from Table 4, the addition of potassium to the hills (against a background of NP) had no effect. Nitrogen alone had little

effect on the increment in yield, but reduced the starch content. The treatment with NP was the most effective, whereby mixtures of simple fertilizers were more effective than either nitrophoska. It must be noted, however, that if we estimate the effect of fertilizers not only from the yield, but also from the amount of starch from 1 ha, Hungarian nitrophoska occupies the first place.

We conducted another experiment on the farm of the Ramensk experiment station of the Scientific Institute of Fertilizers and Insecticides (Table 5). The soil was podzolic, acid clay loam (pH in the salt extract, 4.5; available aluminum, 0.42 meq/100 g; v, 58%).

The reaction of potatoes to the addition of phosphates was high (Table 5). The greatest effect was produced by frozen-out nitrophoska No. 43.

Thus, promising results were obtained from the addition of nitrophoskas with the tubers in various places and in various years. With this method of application compound fertilizers were more effective, as a rule, than equivalent mixtures of simple fertilizers. This can be explained by the fact that the physiological acidity of nitrophoskas is lower than that of ammonium nitrate, and the retrogradation of phosphates is less likely than in superphosphates, while potassium is partially contained in a nitrate form, which is of importance with potatoes (instead of only KCl in the mixture of simple fertilizers).

Sixty-six hectares of potatoes were planted on a production scale with potato planters, and fertilizers were added mechanically during planting, in the kolkhoz "Ogorodnyy gigant" in 1960. At the same time potatoes were planted

Table 3

Influence of various nitrophoskas on the yield and starch content of potatoes in the "Dubki" sovkhos (average from 4 determinations)

Experimental treatment (amounts of N, available P_2O_5 , and K_2O , kg/ha)	Yield and increment of tubers, cntr/ha	D/mD	Starch content %	Yield and increment of starch, cntr/ha	Content in the tubers (% of dry substance)		
					N	P_2O_5	K_2O
Without fertilizer	124	—	13,5	16,6	0,85	0,32	2,15
Frozen-out nitrophoska 16+14; 20; 19+4 ^a	+31	3,9	15,1	+6,8	1,32	0,20	1,71
Sulfatic French nitro- phoska II 20; 20; 23	+37	6,9	13,9	+5,8	0,97	0,23	1,51
Sulfuric Italian nitro- phoska 12+8; 20; 17+6	+43	8,1	14,1	+8,6	1,01	0,21	1,34
NPK 20; 20; 23	+37	6,9	14,4	+6,6	0,79	0,25	1,80
NK 20+23	+12	2,2	14,5	+3,2	1,01	0,22	2,03

^aComposition of nitrophoskas: frozen-out (Dneprodzerzhinsk plant) — 14.3% nitrogen, 17.6% available P_2O_5 , 9.7% water-soluble P_2O_5 , 16.5% potassium. Sulfatic French II — 9.2% nitrogen, 9.5% available P_2O_5 , 7.7% water-soluble P_2O_5 , 11.0% potassium. Sulfuric Italian — 12.1% nitrogen, 20% available P_2O_5 , 20% water-soluble P_2O_5 , 16.5% potassium.

Note: Comma represents decimal point.

Table 4

Comparison between nitrophos and simple fertilizers when placed with the tubers during planting

Experimental treatment	Yield and increment in tubers, cntr/ha	Yield and increment in starch, cntr/ha	Content, %		
			N	P ₂ O ₅	K ₂ O
Without fertilizer	158	20,8	0,88	0,23	1,72
Hungarian nitrophos ^a	+17	+7,6	1,14	0,23	1,71
Italian nitrophos	+16	+4,2	1,13	0,27	1,97
NP	+24	+5,8	0,94	0,28	2,19
N	+4	-1,8	0,97	0,21	1,95
NPK ^b	+22	+5,2	0,89	0,20	1,70

^aComposition of nitrophos: Hungarian — 20% nitrogen, 19.33% total P₂O₅, 14.0% available P₂O₅, 6.2% water-soluble P₂O₅; Italian — 14.6% nitrogen, 30.69% total P₂O₅, 28.3% available P₂O₅, 28.3% water-soluble P₂O₅.

^b23 kg/ha K₂O.

Note: Comma represents decimal point.

Table 5

Effectiveness of the addition of nitrophoska to potatoes during planting at the Pamensk experimental farm of the Institute of Fertilizers in 1960 (average of 4 determinations)

Experimental treatment (amounts of N, available P ₂ O ₅ , and K ₂ O, kg/ha)	Tuber yield and increment, cntr/ha	Starch content, %	Starch yield and increment, cntr/ha	Content in the tubers, % of dry substance		
				N	P ₂ O ₅	K ₂ O
Without fertilizer	131 ^b	10,45	13,69	1,25	0,27	2,05
NPK during plowing 60-60-60	+32	9,55	+1,87	1,62	0,52	2,29
NK dur. plw. (backgr.) 60-60	+12	9,35	-0,32	1,51	0,31	2,12
Background + Ps20 in holes	+32	9,45	+1,71	1,41	0,49	2,35
NK 41-40 + frozen-out nitrophoska No. 43 ^a 19-20-20	+37	10,60	+4,11	1,59	0,53	2,40
NK 44-40 + sulfatic nitrophoska No. 11. 16-20-20	+27	10,15	+2,35	1,54	0,51	2,21

Note: Comma represents decimal point.

^aComposition of nitrophoskas: frozen-out nitrophoska No. 43 — 15.17% nitrogen, 16.02% available P₂O₅, 15.95% K₂O. Sulfatic No. 11 — 10.14% nitrogen, 12.93% available P₂O₅, 12.73% K₂O.

^bAccuracy factor of the experiment, calculated according to the Peregudov method, 3%.

manually on 40 ha in the Gor'kiy kolkhoz in slightly cultivated podzolic soil (pH in the salt extract, 4.8-5.0). The tubers were planted at a rate of 30 cntr/ha. We studied 4 nitrophoskas and equivalent mixtures of simple fertilizers. The yield was low as a result of the prolonged drought in the summer of 1960, even though the differences in the effect of simple and compound fertilizers were pronounced.

As we can see from Table 6, all nitrophoskas, with the exception of frozen-out nitrophoska, were over 4 times more effective in the "Ogorodny gigant" kolkhoz than their equivalent mix-

tures of simple fertilizers. The reason for this was apparently the poor physical properties of the mixtures, which made their even application by machines difficult.

It is interesting to note that frozen-out nitrophoska, which has less satisfactory physical properties (in particular, it deteriorates in storage) than the other compound fertilizers tested, has almost the same effect as a mixture of simple mineral fertilizers. The same year (with the same drought conditions) nitrophoskas and mixtures of simple fertilizers were added by hand on a production scale under the tubers in furrows made by a plow in the

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Table 6

Application of nitrophoskas and mixtures of simple fertilizers during planting of potatoes in production-scale experiments in two kolkhozes (average of 3 determinations) a

Experimental treatment, fertilizers and amounts, kg/ha N - available P ₂ O - K ₂ O	Yield and increment in tubers, cntr/ha		Yield and increment of starch, cntr/ha, Gor'kiy kolkhoz ^c	Content in the tubers, kg/ha			Protein content (%) in tubers, Gor'kiy kolkhoz
	"Ogorodnyy gigant"	Gor'kiy		N	P ₂ O ₅	K ₂ O	
Without fertilizer	82,8	90,2	12,8	30,1	4,0	33,0	1,33
Sulfuric nitrophoska No. 8 ^b							
15. 5-21. 2-26. 9	+24,8	+25,4	+3,8	48,8	6,1	45,1	1,13
NPK 15. 5-21. 2-26. 9	+5,5	+21,4	+3,0	40,1	5,6	41,0	1,31
Sulfuric nitrophoska No. 10							
14. 6-25. 7-27. 2	+25,0	+32,5	+4,4	43,2	7,6	41,2	1,19
NPK 14. 6-25. 7-27. 2	+6,2	+28,7	+3,5	46,8	5,1	44,6	0,93
Sulfatic nitrophoska No. 7							
30. 5-26. 6-25. 2	+33,8	+37,2	+5,1	38,1	8,1	58,6	1,35
NPK 30. 5-26. 6-25. 2	+5,4	+31,7	+4,0	24,2	5,4	38,6	1,01
Frozen-out nitrophoska							
33. 4-24. 0-27. 3	+6,8	+42,5	+5,6	40,3	5,8	73,5	1,21
NPK 33. 4-24. 0-27. 3	+5,6	+34,8	+4,5	40,0	4,9	46,5	1,32

^aThe experimental error (mD) in the "Ogorodnyy gigant" kolkhoz was 4,2 cntr/ha, and in the Gor'kiy kolkhoz, 3,6 cntr/ha.

^bComposition of nitrophoskas: frozen-out — 16.18% nitrogen, 12.02% available P₂O₅, 5.65% water-soluble P₂O₅, 13.71% potassium. Sulfatic No. 7 — 15.27% nitrogen, 13.29% available P₂O₅, 7.44% water-soluble P₂O₅, 12.11% potassium. Sulfuric No. 8 — 7.78% nitrogen, 10.59% available P₂O₅, 6.61% water-soluble P₂O₅, 13.48% potassium. Sulfuric No. 10 — 7.32% nitrogen, 12.85% available P₂O₅, 7.49% water-soluble P₂O₅, 13.61% potassium.

^cStarch was determined after the tubers had been stored for 3 months in a cellar.

Note: Comma represents decimal point.

Gor'kiy kolkhoz, where the soil is slightly cultivated acid clay loam. As we can see from Table 6, with the hand placement of fertilizers under the tubers nitrophoskas were not as effective as when placed by machines. Only the machine placement of fertilizers during planting is promising. This means that for this purpose granulated compound fertilizers are best.

Let us discuss the results of an experiment made in the chernozem zone (kolkhoz in Kalinovka village, Kursk Oblast') in 1960 with Lorch potatoes. Nitrophoskas were applied at the rate of 20 kg/ha of available P₂O₅ and appropriate amounts of N and K₂O against the background of a good base fertilizer (65 kg/ha of N, 55 kg/ha of P₂O₅, and 155 kg/ha of K₂O) during the planting of potatoes with an SKG-4 planter. The yield and increment of tubers in cntr/ha were: 279.4 for the background; + 25.5 for the frozen-out nitrophoska against the background; and +29.0 for the sulfatic nitrophoska against the background. Carbonate nitrophoska, placed in the same manner, had no positive effect.

The reliability factor for the increments, determined according to the Peregodov method, was 2.92 for the frozen-out nitrophoska and 3.47 for the sulfatic nitrophoska; the percentage of error was 1.31 and 1.07, respectively.

The fertilizers increased the starch content of the tubers and therefore the yield of starch increased more than the yield of tubers. Thus, 20.25 cntr/ha of starch were harvested in the

control plot; the increment from the frozen-out nitrophoska was 13.33 cntr/ha and that from sulfatic nitrophoska, 11.28 cntr/ha.²

Several experiments were made by spreading compound and mixed simple fertilizers during plowing or during soil cultivation prior to the planting of potatoes. Thus, in 1958, 45 kg/ha each of N, available P₂O₅, and K₂O were added in the form of sulfuric nitrophoska or mixed simple fertilizers to the slightly acid, slightly humic, sod-moderately podzolic soil of the "Put' Il'icha" kolkhoz in the Moscow Oblast' (Table 7).

The uptake of nutrients by the plants may be judged from the analysis of potato leaves, made twice during the growing period (Table 7).

The methods of analysis were the same as in one of the preceding experiments.

The total nitrogen content in the leaves of fertilized plants was considerably higher, while

²The composition of frozen-out nitrophoska was given earlier. Sulfuric nitrophoska No. 19 contained: 10.6% nitrogen; 11.93% total, 11.31% available, and 5.6% water-soluble P₂O₅; and 13.8% K₂O. The addition of 20 kg/ha of available P₂O₅ in the frozen-out nitrophoska gave 16.1 kg/ha nitrogen and 18.7 kg/ha K₂O.

The same amount of available phosphorus in the sulfuric nitrophoska gave 18.7 kg/ha nitrogen and 22.6 kg/ha K₂O.

Table 7

Potato yield and quality against a background of two combinations of fertilizer

Experimental treatment	Tuber yield and increment, cнtr/ha	Starch content, %	Starch yield and increment, cнtr/ha	Content in the shoot (% of dry substance) 1 mo. before harvest		
				N	P ₂ O ₅	K ₂ O
Without fertilizer	85	10,6	9,0	3,16	0,61	2,64
Nitrophoska	+42	11,1	+6,1	3,69	0,72	2,72
NPK	+24	10,4	+4,3	3,60	0,71	2,70

Note: Comma represents decimal point.

that of phosphorus was slightly higher, whereby there was practically no difference between nitrophoska and the mixture of simple fertilizers. The percentage of potassium was similar under all the treatments. But the absolute content of these substances was higher in the yield from fertilized plots, since the harvest was much better from the fertilized plots than from the control.

The increment in tuber yield, the starch content of the tubers, and the starch harvest were considerably higher with nitrophoska than with the equivalent mixture of simple fertilizers, even though this mixture was in its turn much superior than the control.

The experiments with broadcasting of various nitrophoskas and their equivalent mixtures of simple fertilizers over plowed fields were made in 1960 with potatoes on another 2 farms. In the "Ogorodnyy gigant" kolkhoz (same field) equal yield increments were obtained from compound and simple fertilizers (Table 8).

It must be noted that nitrophoska No. 7 gave better results than the frozen-out nitrophoska. This is apparently attributable to the more favor-

able ratio between nutrients in nitrophoska No. 7 and the relatively high content of water-soluble phosphates in it.³ The removal of nutrients by the potato harvest was approximately the same with nitrophoskas and equivalent mixtures of simple fertilizers.

Two nitrophoskas were used in the "Gorodishche" sovkhov (slightly podzolic medium clay loam soil with a pH of 5.4 in the salt extract). Two thirds of the amount of nitrophoska was added during plowing in spring and one third and an equivalent amount of nutrients in simple fertilizers were added before planting. The potato yield was low because of a drought, but differences between the action of the fertilizers studied were still noticeable (Table 9).

In spite of the higher amount of nitrogen and potassium in the carbonate nitrophoska, it was very inferior to the mixture of simple fertilizers, especially to frozen-out

³ The composition of both nitrophoskas was given earlier.

Table 8

Effect of compound and simple fertilizers on potatoes when broadcast before planting in the "Ogorodnyy gigant" kolkhoz

Experimental treatment (amounts of N, available P ₂ O ₅ , and K ₂ O, kg/ha)	Tuber yield and increment, cнtr/ha	Starch yield and increment, cнtr/ha	Content in the tubers, kg/ha		
			N	P ₂ O ₅	K ₂ O
Without fertilizer	82,8	7,5	30,1	4,0	33,0
Sulfatic nitrophoska					
No. 7 61-53-50	+45,4	+2,5	38,4	8,32	57,6
NPK 61-53-50	+46,4	+3,1	45,12	7,10	62,04
Frozen-out nitrophoska					
67-48-55	+32,2	+1,7	36,8	7,80	63,2
NPK 67-48-55	+35,0	+1,0	35,4	8,6	73,8

Note: The yield increments as compared to the control are reliable; the difference between nitrophoskas and mixtures is unreliable.

Note: Comma represents decimal point.

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Table 9

Increment in the yield of Epron potatoes from broadcasting simple and compound fertilizers in the "Gorodische" sovkhos in 1960 (average from 4 determinations)

Experimental treatment (amounts of N, P ₂ O ₅ , and K ₂ O, kg/ha)	Tuber in- crement, cntr/ha	Reliability of the differences (D/mD)	Increment in the yield of dry sub- stances, cntr/ha	Increments			
				In the starch yield, cntr/ ha	In the content of nu- trients in potato tubers and shoots, kg/ha		
					N	P ₂ O ₅	K ₂ O
Carbonate nitrophoska ^a							
84-45-84	+19,0	+15,1	+5,6	+2,47	+21,8	+1,83	+19,9
NPK 84-45-84	+25,0	+ 6,7	+7,4	+3,01	+22,0	+1,33	+22,6
Frozen-out nitrophoska							
35-45-32	+30,1	+ 8,1	+8,9	+4,47	+26,8	+2,11	+21,4
NPK 35-45-32	+25,8	+ 6,7	+8,0	+3,48	+27,6	+1,28	+19,4

^aContent of nutrients in the carbonate nitrophoska: 14.9% nitrogen, 7.96% available P₂O₅, and 14.9% K₂O. The frozen-out nitrophoska was described earlier.

Note: Comma represents decimal point.

nitrophoska. This is attributable to the fact that carbonate nitrophoska was granulated and did not contain water-soluble phosphoric acid salts; all this made the uptake of phosphates by plants difficult the first year when the interaction between the fertilizer and the soil and roots was limited and short-lived.

Frozen-out nitrophoska was superior to the mixture of simple fertilizers.

Experiment with Bizon tomatoes — made in 1959 on cultivated, slightly acid sod-podzolic clay loam soil (1.9% humus, pH of the salt extract, 6.1, v, 80.4%) at the experiment station of the Institute of Vegetable Growing (Moscow Oblast'). The effect of a number of nitrophoskas and their equivalent mixtures of simple fertilizers, applied locally (in hills when transplanting the seedlings), was compared. All fertilizers were rated according to the available P₂O₅ (20 kg/ha). The results are presented in Table 10.

As we can see from Table 10, the most effective amount and the best ratio between nitrogen, phosphates, and potassium for application during planting of tomatoes on this soil was 20 kg/ha of each (1:1:1). Under this treatment frozen-out nitrophoska No. 82 was much better than the French nitrophoska II and much superior to the equivalent mixture of simple fertilizers in its effect on the yield and quality of the fruit. When the amount of nitrogen or potassium was reduced or increased, and that of phosphates was left the same, the effectiveness of both nitrophoskas and mixtures of simple fertilizers decreased. All the nitrophoskas tested, except the Rotterdam carbonate nitrophoska, contained not less than half of the phosphates in a water-soluble form, and in this respect they were equal to each other in the composition of phosphates. Consequently, the decisive role was played by the N:P₂O₅:K₂O ratio in the fertilizer and the amount of nutrients per hectare.

The dynamics of the uptake of nitrogen,

phosphoric acid, and potassium by the tomatoes is shown in Figure 1-A. It shows that the compound fertilizers studied were as available as the mixtures of simple fertilizers. But nevertheless, the availability of all ions to plants was somewhat greater in the frozen-out nitrophoska.

The N, P₂O₅, and K₂O content in the tomato tops during the flowering stage is shown in Table 10. The nitrogen content was highest in plants on sulfuric nitrophoska and frozen-out nitrophoska. The phosphate content was highest with the mixture of simple fertilizers, Italian nitrophoska, and frozen-out nitrophoska. It must be noted that in the first two fertilizers almost all the phosphoric acid was in a water-soluble form. The differences were less for potassium: its content was high with all the fertilizers.

Experiments with late Moscow cabbage were made at the same experiment station, but on a more acid soil (1.85% humus, pH of salt extract, 5.4, v, 70.6%), the same year as with the tomatoes. The fertilizer was broadcast during plowing. The amounts used were: 130 kg/ha nitrogen, 80 kg/ha available P₂O₅, and 190 kg/ha K₂O. These amounts and ratios between nutrients are optimum for obtaining a high yield on the given soil (according to M. I. Gusev). The results of the experiments are summarized in Table 11.

The greatest yield of cabbage heads and sugar content (Table 11) was obtained from frozen-out nitrophoska No. 82, but all the other compound fertilizers, including carbonate nitrophoska No. 89, had a better effect on the yield and quality of cabbage heads than the mixture of simple fertilizers.

The content of total nitrogen, phosphates, and potassium in the stage of the formation of the heads was highest over NPK and lowest on carbonate nitrophoska. The dynamics of the uptake of N, P₂O₅, and K₂O presented in Figure 1-B, which shows that the accumulation

Table 10

Tomato yield and quality of fruits after local application of fertilizers to sod-podzolic clay loam soil in 1959 (average from 4 determinations)

Fertilizers and their content in N, available and water-soluble P_2O_5 and K_2O , %	Amounts of N, P_2O_5 , and K_2O , kg/ha	Yields and increments, cntr/ha	Sugar yield and increment cntr/ha	Cotton, % of dry substance				
				Protein	Organic acids ^a	N	P_2O_5	K_2O ^b
				During harvest		In the flowering stage		
Without fertilizer	—	192,8	+6,1	13,2	0,49	3,65	0,90	4,19
Frozen-out nitrophoska No. 82 14.04; 16.04; 8.24; 17.58	20—20—20	+183,6	+8,2	15,6	0,63	4,92	0,93	4,53
Sulfatic French nitrophoska II 9.22; 9.40; 8.08; 11.1	20—20—20	+163,3		Not det'd.				
NPK	20—20—20	+136,6	+4,8	15,0	0,65	4,80	0,90	4,36
Sulfuric nitrophoska No. 13 12.82; 7.91; 3.05; 18.8	33—20—33	+ 88,8	+3,7	13,5	0,60	5,24	0,91	4,72
Sulfuric nitrophoska No. 17 12.13; 7.94; 4.87; 18.22	33—20—33	+ 78,9		Not det'd.				
NPK	33—20—33	+106,8	+3,4	13,7	0,55	4,66	1,02	4,72
Sulfuric French nitrophoska I 7.95; 12.63; 3.73; 16.95	10—20—20	+155,6	+8,1	13,3	0,54	4,61	0,87	4,89
Carbonate Rotterdam nitrophoska 10.5; 10.33; 0.67; 21.25	10—20—20	+136,9		Not det'd.				
NPK	10—20—20	+153,4	+6,7	14,1	0,52	4,61	0,94	4,79
Sulfuric Italian nitrophoska 10.0; 20.0; 20.0; 15.0	10—20—15	+ 97,2	+3,3	13,8	0,54	4,69	0,86	4,54
NPK	10—20—15	+105,9	+3,5	13,9	0,51	4,58	0,76	4,44

^a As reduced to malic acid, % of dry substances.

^b Total nitrogen was determined by the Kjeldahl method (micromodification); total content of phosphoric acid was determined photocolrimetrically according to the Deniege method as modified by Levitskiy (after wet ashing according to the Lebedyantsev method); total potassium content was determined after dry ashing according to the Tananayev method (weighing method in the form of a complex of potassium-silver cobalt nitrite).

Note: Comma represents decimal point.

of all these substances in the cabbage was similar under all the treatments. The results of the analysis of the yield during the harvest are presented in Table 12.

As compared to the control, the percentage of all the substances studied was higher in all the parts of cabbages from fertilized plots. The heads grown under the best treatment — with nitrophoska No. 82, had a somewhat higher content of nitrogen and phosphorus. The

maximum potassium content was found in plants grown on a mixture of simple fertilizers.

Conclusions

The production of compound nitrophoska and nitrophos fertilizers in the USSR must increase considerably in the current 7-year plan. In addition to technical and economical advantages of their production, these fertilizers

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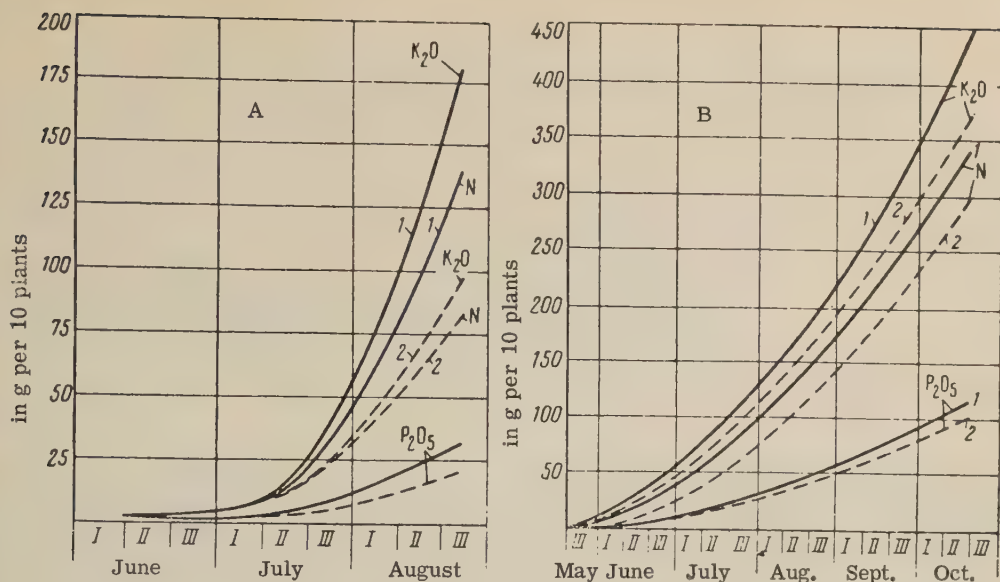


Fig. 1. - Graph of the removal of nutrients.
A - by tomatoes; B - by cabbage. 1 - with nitrophoskas; 2 - with mixtures.

Table 11

Effectiveness of various nitrophoskas on cabbage (average of 4 determinations)

Experimental treatment	Yield and increment of cabbage heads, ctnr/ha	Sugar content, %			Sugar yld. and increment, ctnr/ha	Content (% of dry substance) during formation of the heads		
		Mono-saccharide	Disaccharide	Total		N	P_2O_5	K_2O^b
Without fertilizer	522,9	3,64	0,14	3,78	19,7	5,46	1,22	6,29
Nitrophoskas:					Not det'd.			
sulfuric No. 13	+130,2							
sulfuric No. 17	+151,4	4,00	0,23	4,23	+10,0	5,84	1,38	6,26
frozen-out No. 82	+187,6	3,88	0,34	4,22	+11,6	6,01	1,45	6,45
carbonate No. 89 ^a	+150,7	4,04	0,16	4,20	+ 9,8	5,13	1,31	6,24
NPK	+102,1	3,64	0,20	4,38	+ 9,0	6,21	1,48	6,82

^aNitrophoskas Nos. 13, 17, and 82 were described in Table 10, carbonate nitrophoska No. 89 contained: 13.95% nitrogen, 9.37% available P_2O_5 , and 18.24% K_2O .

^bThe method of analysis was the same as for tomatoes.

Note: Comma represents decimal point.

will be of considerable advantage to agriculture, since they would eliminate the costly work of crushing, sieving, and mixing simple fertilizers at sovkhoses and kolkhoses. Moreover, the production of compound fertilizers in granular form makes their placement with combined spreaders, transplanting and planting machines, and potato planters in rows, hills, and holes easier. These local methods of using small amounts of fertilizer can be very effective.

Our experiments on sod-podzolic soils of the Moscow Oblast' showed in an average of 12 comparisons that when fertilizers were added locally the yield of potato tubers reached (in % over the control) 28.6% from nitrophoskas and 25.5% from an equivalent mixture of simple fertilizers. The increase in starch yield (also in % over the control) was 34.2% and 25.6%, respectively.

The mechanized application of a mixture of

Table 12

Nutrient contents in the cabbage during the harvest, % of dry substance

Experimental treatment	Core			Leaves		K ₂ O	Heads		
	N	P ₂ O ₅	K ₂ O	N	P ₂ O ₅		N	P ₂ O ₅	K ₂ O
Without fertilizer	1,41	0,78	2,42	1,81	0,54	2,18	1,62	0,64	2,34
Nitrophoskas:									
No. 17	1,49	0,87	3,02	2,24	0,58	2,24	2,13	0,64	2,77
No. 82	2,13	0,79	2,96	1,95	0,56	2,55	2,28	0,67	2,90
No. 89	1,79	0,82	2,66	2,02	0,57	2,01	2,06	0,64	2,71
NPK	1,97	0,73	2,95	2,39	0,62	2,09	2,08	0,64	2,94

Note: Comma represents decimal point.

simple fertilizers is made difficult by the unsatisfactory physical properties of the mixture. Thus, in an experiment on a production level on 66 ha in the "Ogorodnyy gigant" kolkhoz the 3 sulfuric nitrophoskas studied produced an increase of 29.5 cнtr/ha (a 35.6% increase over the control) when placed during the planting of the tubers with the KSG-4 planter, while equivalent mixture of simple fertilizers produced an increase in tuber yield of only 5.7 cнtr/ha (+ 6.9%).

When the fertilizers were broadcast during plowing potatoes also reacted better to sulfuric and frozen-out nitrophoskas than to equivalent mixtures of simple fertilizers. The average increment from 4 comparisons of tuber yield (in % over the control) was 48.6% from nitrophoskas, and 42.7% from NPK; the same was true of the starch yield.

The local placement of frozen-out nitrophoska during the transplanting of tomatoes produced an increment of 95% in fruit yield, while the mixture of simple fertilizers produced an increase in yield of 70.8% over that of the control (192.8 cнtr/ha). The sugar and protein content in the fruits was higher with nitrophoska. The same nitrophoska was the most effective of all the nitrophoskas tested when used as the base fertilizer for cabbage, producing an increase in the yield of cabbage heads of 34% (while the mixture of simple fertilizers produced an increase of 18.4% as compared to the control — 523 cнtr/ha).

Thus, compound fertilizers must preferably be used for row crops.

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FERTILITY OF SOILS IN THE VIRGIN REGION

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In accordance with the resolution of the February-March 1954 Plenum of the Communist Party of the USSR on the increase in grain production in our country, the Timiryazev Academy (in cooperation with the Moscow Institute of Land Management) organized 5 complex expeditions to the northern regions of Kazakhstan: the Tselinograd, Aktyuba, Western-Kazakhstan, Pavlodar, and Kokchetav Oblast's at the request of the Ministry of Higher Education of the USSR.

From 1954 to 1960 the expeditions of the Timiryazev Academy studied 8.9 million hectares of virgin land. Many new sovkhoses have been organized in the discovered arable areas.

The results of detailed field and laboratory studies of the specific natural conditions and properties of soils in the virgin region make it possible to a certain degree to perceive the history of the formation of these soils and establish the principles of their development under the effect of vegetation and human agricultural activity.

The territory of the Virgin Region of Kazakhstan is divided in 3 natural zones: the forest-steppe, the steppe, and the dry steppe. These differ considerably in their climate, vegetation, and soil. Ordinary chernozems predominate in the forest-steppe, southern chernozems in the steppe, and soils of the chestnut group in the dry steppe.

Virgin chernozems and dark-chestnut soils developed under the long-term influence of perennial meadow, meadow-steppe, and steppe grasses.

According to Dokuchayev (2), Kostychev (5), Izmail'skiy (4), and other investigators, virgin steppes were covered in the past by high and dense grass consisting of grasses, mixed herbage, and steppe shrubs (dwarf almond, wild cherry, etc.), covering 80%-90% of the chernozem zone and 60%-70% of the chestnut zone. A layer of steppe mat formed at the surface. Later the virgin steppes changed noticeably under the effect of the natural process of soil formation, cattle grazing, steppe fires, mowing, and primitive soil tillage during the period of the idle land system of agriculture.

Feather grass and sheep's fescue took over in the chernozem steppe and the shrubs disappeared. The coverage by vegetation diminished to 60%-70%. Vegetation in the dry steppe became even rarer. Here coverage by vegetation decreased to 40%-60%, xerophytic shrubs (wormwood, kochia) and salt tolerant plants (camphoroma, Russian thistle, etc.) appeared, and vegetation-free areas became covered with algae and lichens. As a result of this the biological productivity of the steppe also decreased.

By the biological productivity of the steppe we mean the annual yield of the tops and roots in centners per hectare. However, as our investigations showed, biological productivity is still at a sufficiently high level. To assess the biological productivity in typical location we cut the grass to the ground from a 1 m square area, replicated 3-4 times. Monolith sections of soil 20 x 30 x 20 cm in size were cut and the roots washed. The results of our investigations are presented in Table 1.

From the data in Table 1 we can see that the greatest amount of tops was collected from virgin meadow-chernozem soil and the least, from solonchic chestnut soil. The total amount of organic matter decreases as we go from chernozem soils to chestnut soils, but at the same time the ratio of roots to tops increases from 6 to 35, which is attributable to the biological peculiarities of the grasses and the increasing dryness of the climate in the chestnut soil zone.

As we go from the weed-covered abandoned land to virgin land the amount of tops first increases and reaches a maximum on the abandoned land covered with couch grass and then decreases in the virgin land, whereas the amount of roots remain increases sharply. The ratio between roots and tops in the ordinary chernozem varies from 1.9 to 6. Thus, as abandoned land changes to virgin land the shoot yield decreases and the roots accumulate. On the whole, however, the amount of organic matter increases as we go from one stage of abandoned land to another, which is an indication of the progressive increase in soil fertility as old plowland becomes abandoned land. A similar restoration of soil fertility takes place when perennial grasses are sown, which accumulate relatively more root residues

Table 1

Contents of tops and roots in the 0-20 cm layer

Soil	Vegetation, land use	Mass of		Ratio of roots to tops	Total amount of organic mass
		Tops	Roots		
Ordinary chernozem, Kokchetav Oblast'	Mixed herbage-sheep's fescue-feathergrass virgin land	46,0	278,0	6,0	324,0
	Weed-covered old fallow	34,0	67,0	1,9	101,0
"	Couch grass on 4-year old idle land	54,0	165,0	3,1	219
"	Awnless brome grass after 3 years of use	66,0	178,0	2,7	244,0
Meadow-chernozem, Kokchetav Oblast'	Mixed-grass virgin land	56,3	423,0	7,5	479,3
Southern chernozem, Pavlodar Oblast'	Sheep's fescue-feathergrass virgin land	28,0	251,0	9,0	279,0
	Agropyron after 5 years of use	32,0	119,0	3,7	151,0
Dark-chestnut, Western Kazakhstan Oblast'	Sheep's fescue-feathergrass virgin land	11,0	233,0	21,4	244,0
Chestnut	Feathergrass-sheep's fescue virgin land	6,0	177,0	29,5	183,0
	Agropyron after 2 years of use	6,0	116,0	7,2	132,0
Solonetzic chestnut	Wormwood-sheep's fescue virgin land	4,0	143,0	35,7	147,0

Note: Comma represents decimal point.

than annual cultivated plants.

The decomposition rate of plant residues depends on the composition of the plants, the degree of wetness, soil temperature, and the intensity of microbiological processes. The residues of virgin vegetation decompose most slowly. Therefore they can be found in the soils of the Virgin Region 8-10 years after plowing.

The decomposition of organic residues after the plowing of virgin land depends also on the method of soil tillage and the preceding crop (Table 2).

As we can see from Table 2, virgin land contains the largest amount of plant residues. Their amount decreases by 30% in the fallow a year after the virgin land is plowed. The following years the plant residues of the virgin land decompose and a certain amount accumulates from annual crops (spring wheat). However, the plant residues decompose much more rapidly in the plowed field than they accumulate. Therefore, as the virgin land is used for agricultural crops its total content of plant residues decreases. Our data show that decomposition depends also on the method of soil tillage.

In addition, from Table 2 we can see that there are more organic residues in soil plowed in the fall than in a fallow field. This is attributable to the fact that microbiological processes

attenuate in the soil in the fall when plowing is done. Under the conditions prevailing in the Virgin Region the soil remains cold for a long time in the spring so that the development of microbiological processes is also inhibited. The limiting factor for decomposition in summer is the moisture deficiency under cultivated plants. The conditions for the decomposition of plant residues are more favorable in a fallow field, since the friability of the plowed layer and the presence of moisture there promote the development of bacteria which decompose the organic matter in the soil. The decomposition of virgin plant residues ends 8-10 years after the virgin land has been plowed. Thereafter the amount of organic residues in the soil becomes more or less constant for each soil group and method of tillage. The amount of organic residues can be increased considerably by sowing perennial grasses. The decomposition of organic matter is directly related to the intensity of microbiological processes in the soil and the nature of the microflora (Table 3).

As we can see from Table 3, the total amount of microorganisms in the upper layer (0-10 cm) is greater in old arable land than in virgin land. Development of separate groups of microorganisms completely conform with the conditions created in the virgin and old cultivated lands. Denitrifying and cellulose-decomposing microorganisms are widespread in virgin soils with a large amount of organic matter, while aerable and ammonifying microorganisms predominate in the more friable old arable soils.

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Table 2

Change in the content of plant residues in virgin chernozem after plowing

Land use	Organic residues	
	cntr/ha	% in relation to vir. land
Virgin land	420	100
Fallow of virgin land	296	70
Second year seed, aft. shal. cultiv.	279	66
Fallow after 4th year of plowing virgin land	173	41
Fall plowed field after 6th year of plowing virgin land	214	51
Fall-plowed field 30-yr. arab. ld.	114	27
Fallow on 30-yr. old arable land	75	18
Couch grass after 4 years of use on 30-year old arable land	258	61

Table 3

Total amount of microorganisms in chernozems, in thousands per 1 g of absolutely dry soil

Land use	Depth, cm	Total amount		Ammoni- fyers	Denitri- fyers	Nitrify- ers	Anaerobic cellulose decom- pos- ers
		Aerobic	Anaerobic				
		Ordinary chernozem					
Virgin land	0—10	7030	20900	1100	1100	10	—
Spring wheat on virgin land fallow disced to a depth of 8-10 cm	10—20	6040	15150	10300	1000	10	7,21
	0—10	153516	77390	10900	1100	109	9,81
Spring wheat on virgin land fallow plowed to a depth of 22-25 cm	10—20	4056	12480	1040	1050	104	21,84
	0—10	18939	127330	10700	1050	107	8,56
Spring wheat on fallow of old arable land	10—20	17100	29400	10500	1050	105	13,65
	0—10	12566	36050	20300	1030	103	10,30
	10—20	10450	49220	20700	1070	107	16,05
Fallow of old arable land	0—10	5618	26500	10750	1060	106	18,02
	10—20	13750	33000	11000	1110	110	29,70
		Southern chernozem					
Virgin land	0—10	5500	220	11	2220	—	33,00
	20—30	6720	1120	224	3360	—	22,40
Old arable land	0—10	28890	1284	3210	107	—	214
	20—30	3870	129	193	2580	—	258

Note: The soil samples for microbiological analysis were collected by Ye. V. Kulakov and A. P. Mershin. The analyses were made by V. F. Nepomiluyev at the Chair of Soil Science of the TSKHA.

Note: Comma represents decimal point.

The nitrate content in the soil is also an indication of the intensity of microbiological processes. According to our data up to 50

mg of nitrates per 1 kg of soil accumulates in old arable soils, while only 2-3 mg/kg of soil accumulates in virgin lands.

The changed conditions of microbiological activity in plowed soils unavoidably effect a change in physicochemical properties. The activation of aerobic microorganisms in plowed soils leads to the decomposition not only of organic residues, but also of a certain part of the former humus, as a result its amount decreases (Table 4).

As we can see from the data in Table 4, the decomposition of humus in virgin land uses for agricultural crops which take up nitrogen is most intense in the upper 30 cm of the soil. Below this layer the humus and nitrogen content in the soil remains practically unchanged a very long time (50-100 years). Within the upper 30 cm of the soil the most intense humus decomposition and nitrogen loss occurs in its uppermost part during the first years after the virgin land is plowed. Then the intensity of humus decomposition and nitrogen loss decreases gradually, which can be judged by the annual rate of humus decomposition. Thus, the decrease in the amount of humus in dark-chestnut soil (Izhevskiy sovkhov) was 17.2 metric tons/ha in 30 years. Consequently, its annual decrease as compared to its content in virgin land was 0.57 metric tons/ha, or 1.1%. The loss of nitrogen was correspondingly 0.3 metric tons/ha, or 0.6%. In the first 5 years

the amount of humus decreased by 12.2 metric tons/ha, or 2.3%, and that of nitrogen, by 0.2 metric tons/ha, or 1.8% of its total amount in virgin land. One-hundred years after the plowing of virgin land in ordinary chernozem the annual loss of humus was only 0.24% and that of nitrogen, 0.25%. The decomposition of humus and the loss of nitrogen are slowest in southern calcareous chernozems. The average annual loss of humus here is 0.07% and that of nitrogen, 0.02%. This is apparently attributable to the fact that processes of humus decomposition predominate over the process of synthesis in old arable ordinary chernozem under permanent annual crops. The decomposition of humus is less intense in southern calcareous chernozem because of the dryness of the soil during the growing period.

It must be noted that the humus in old arable chernozems is relatively resistant to decomposition. This characteristic of chernozem soils ensures the long-term preservation of their fertility.

When virgin land is plowed humus changes not only quantitatively, but also qualitatively. This change is manifested in the relative increase of the available portion of humus (Table 5).

From Table 5 we can see that the amount of humic

Table 4
Humus and nitrogen content in virgin and plowed soils

Depth, cm	Virgin land				Old arable land			
	Humus		Nitrogen		Humus		Nitrogen	
	%	m ton/ha	%	m ton/ha	%	m ton/ha	%	m ton/ha
Ordinary chernozem, "Parizhskaya kommuna" kolkhoz, Kokchetav Oblast', about 100-year old arable land								
0-10	7.02	71.91	0.366	3.84	5.76	54.14	0.291	2.74
10-20	6.92	74.73	0.345	3.72	5.76	55.29	0.283	2.72
20-30	5.32	60.11	0.294	3.31	4.40	44.44	0.259	2.62
40-50	3.00	38.10	0.162	2.05	3.12	42.43	0.181	2.56
50-60	2.40	32.40	0.133	1.79	2.83	38.97	0.166	2.27
60-70	1.32	31.22	0.122	1.64	2.51	34.13	0.150	2.04
70-80	1.69	23.99	0.090	1.27	1.98	28.52	0.120	1.73
80-90	1.27	18.03	0.074	1.05	0.76	10.94	0.047	0.68
90-100	0.55	7.92	0.023	0.33	0.53	7.57	0.032	0.45
	—	413.40	—	22.22	—	361.64	—	20.45
Southern chernozem, Stalin kolkhoz, Tselinograd Oblast', about 50-year old arable land								
0-10	5.52	52.79	0.356	3.41	5.53	54.77	0.361	3.57
10-20	4.67	53.30	0.310	3.47	5.54	55.95	0.360	3.53
20-30	3.77	49.28	0.223	2.92	3.69	42.80	0.198	2.29
30-40	3.52	44.35	0.208	2.42	3.51	43.52	0.192	2.38
40-50	3.47	46.12	0.191	2.54	3.13	41.94	0.186	2.49
50-60	2.49	34.36	0.138	2.16	2.58	36.89	0.149	2.13
60-70	1.73	25.77	0.096	1.43	1.62	24.13	0.094	1.40
70-80	1.59	26.96	0.083	1.30	1.32	20.59	0.089	1.38
80-90	0.81	12.87	0.074	1.17	0.66	10.42	0.063	0.99
90-100	0.29	4.61	0.045	0.71	0.21	3.33	0.039	0.62
Total	—	350.41	—	21.53	—	334.34	—	20.38

Note: Comma represents decimal point.

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Table 5

Qualitative characteristics of humus in the 0-10 cm layer of dark-chestnut soil

Humus composition	Virgin land	30-year old arable land
Total carbon content in the soil, %	3,1	2,2
Sum of humic acids in % of carbon	36,3	40,9
Sum of fulvic acids in % of carbon	25,3	24,7
Ratio of the sum of humic to fulvic acids	1,4	1,7

Note: Comma represents decimal point.

acids increases, while the content of fulvic acids decreases somewhat in old arable soils. Because of this the ratio of humic acids to fulvic acids increases in old arable land as compared to virgin land.

As we have mentioned earlier, when we go from ordinary chernozems to southern chernozem and then to dark-chestnut soil, the total amount of tops decreases, while the roots in-

crease, which is associated to a large degree with the change in the species composition of virgin vegetation in which xerophytes begin to predominate. Each plant species is characterized by a specific chemical composition (Table 6).

The results of a chemical analysis of vegetation (Table 6) show essential differences in the ash composition and nitrogen content of

Table 6

Chemical composition of the ash of plant associations and individual plants, %

Plant association. Soil	Parts of plants	Pure ash	Nitrogen	SiO ₂	R ₂ O ₃	CaO	MgO	P ₂ O ₅	K ₂ O	Na ₂ O
		% of dry substance		% of pure ash						
Carrot-sheep's fescue-feathergrass. Ordinary chernozem	Tops	7,11	1,33	41,07	1,99	16,2	2,42	3,53	29,32	0,4
	Roots	7,19	1,68	40,84	2,08	15,12	3,25	4,03	12,95	—
Mixed herbage-feathergrass-sheep's fescue Solonetzic chernozem	Tops	7,48	1,26	48,71	1,84	7,44	1,86	3,94	19,55	1,81
	Roots	11,42	1,61	32,85	2,75	8,96	1,71	6,81	5,37	—
Mixed herbage-grass Meadow-chernozem	Tops	7,81	1,30	46,71	—	15,01	2,13	2,04	26,45	—
	Roots	9,92	1,59	44,21	3,10	16,16	2,65	4,73	13,57	—
Mixed herbage-grass Solodized meadow-chernozem	Tops	10,14	1,49	48,83	1,45	10,84	2,27	—	20,71	—
	Roots	7,20	1,75	36,67	4,41	24,98	2,81	5,46	17,30	—
Feathergrass <i>Stipa Lessingiana</i> Trih	Tops	8,95	1,14	70,06	14,43	10,30	1,83	2,16	3,18	0,42
	Roots	5,97	0,81	55,07	9,25	18,24	5,57	1,74	1,44	0,85
Sheep's fescue <i>Festuca Sulcata</i> Haxc	Tops	11,87	2,11	74,84	4,62	4,32	1,23	1,49	7,45	1,28
	Roots	14,38	0,79	62,89	10,07	11,17	1,51	0,90	7,70	0,98
White wormwood <i>Artemisia incana</i> Kell	Tops	16,60	0,77	66,45	2,54	5,70	3,58	0,80	18,0	0,86
	Roots	6,67	0,52	46,67	4,34	11,00	4,70	2,39	21,33	5,19
Thrift <i>Statice Gmelini</i> Wild	Tops	6,33	—	16,16	38,86	13,58	2,18	2,50	24,96	2,08
	Roots	6,51	—	30,33	24,59	12,81	2,87	3,20	21,89	2,88
Black wormwood <i>Artemisia pauciflora</i> Well	Tops	12,25	1,45	44,48	14,27	9,21	1,63	3,10	11,59	8,49
	Roots	6,12	0,11	33,03	17,76	10,64	1,96	5,21	18,79	6,48
Spring wheat. Ordinary chernozem	Roots	8,00	0,53	35,08	3,46	18,66	2,71	4,23	8,97	—

Note: Samples 1-4 and 10 were analyzed by Maysuryan (6) and 5-9 by Zenin (3).
Note: Comma represents decimal point.

various plant associations and individual plants on chernozem and dark-chestnut soils. The ash content of plant associations on chernozems and meadow-chernozem soils varies in the tops from 7% to 10% and in the roots from 7% to 11%. The ash content of individual plants varies within wider limits, from 6% to 17%.

The following elements predominate in the ash composition of plant associations on chernozem and meadow-chernozem soils: silica, potassium, and calcium, whereby these elements are unevenly distributed in the various parts of the plants. The ash in the plant tops contains more potassium and less calcium, while in the roots there is more calcium and less potassium. The sodium content in the ash increases sharply in the tops, as well as the amount of sesquioxides in the roots on solonchic chernozem.

The ash of grasses typical of chernozem (feathergrass, sheep's fescue) contains a large amount of silica (55%-70%), while the ash of plants characteristic of solonchets (thrift, wormwood) contains a large amount of alkali cations. The last fact is the reason for the accumulation of readily soluble alkali cation salts in saline soils. In contrast to the root system of grass-mixed herbage associations of virgin chernozems, the roots of spring wheat contain less silica, and somewhat more alkali metals, nitrogen, phosphorus, and potassium than the roots of virgin vegetation.

The quantitative aspect of the biological cycle of substances may be judged from the ash elements and nitrogen which enter the soil annually with the plant litter (Table 7).

As we can see from Table 7, the greatest amount of mineral substances involved in soil formation is supplied by the mixed herbage-feathergrass vegetation of meadow-chestnut soil (14.98 cntr/ha), next by the mixed herbage-grass vegetation of meadow-chernozem soil (13.29 cntr/ha), then by the vegetation of solonchic chernozem (5.39 cntr/ha), and finally by the black wormwood solonchic vegetation (2.84 cntr/ha).

The greatest amount of nitrogen is supplied to meadow-chernozem soil by the residues of mixed herbage-grass vegetation (2.33 cntr/ha) and the least amount, by black wormwood (0.08 cntr/ha).

The largest amount of phosphorus is contained in carrot-sheep's fescue-feathergrass (45 kg/ha) and mixed herbage-feathergrass (32 kg/ha) vegetation. The largest amount of alkali earth cations is supplied annually by the remains of mixed herbage-grass (2.90 cntr/ha) and mixed herbage-feathergrass (2.88 cntr/ha) vegetation, and the least, by black wormwood on solonchets. A comparison of the amount of ash elements supplied to the soil by the tops and roots shows that the main

Table 7

Several characteristics of the biological cycle of ash substances and nitrogen in soils of the Virgin Region in the 0-20 cm layer, cntr/ha

Plant associations. Soil	Parts of plants	Is supplied annually to the soil ^a							
		Ash	Nitrogen	SiO ₂	R ₂ O ₃	CaO	MgO	P ₂ O ₅	K ₂ O+NO ₂ O
Carrot-sheep's fescue-feathergrass. Ordinary chernozem	Tops	1,63	0,10	0,69	0,03	0,27	0,04	0,03	0,50
	Roots	7,66	1,38	3,12	0,16	1,16	0,24	0,39	0,99
Mixed herbage-feathergrass-sheep's fescue. Solonchic chernozem	Tops	1,12	0,06	0,55	0,02	0,08	0,02	0,04	0,22
	Roots	4,27	0,66	1,30	0,12	0,36	0,07	0,28	0,23
Mixed herbage-grass. Meadow-chernozem	Tops	1,89	0,10	0,89	—	0,28	0,04	0,04	0,50
	Roots	11,40	1,82	5,05	0,35	1,34	0,31	0,54	1,55
Mixed herbage-grass. Solonchic meadow-chernozem	Tops	2,52	0,12	1,23	0,04	0,27	0,06	—	0,52
	Roots	9,24	2,21	3,39	0,41	2,31	0,26	0,51	1,60
Sheep's fescue-feathergrass. Dark-chestnut	Tops	1,07	0,13	0,75	0,16	0,13 ^b		0,02	0,04
	Roots	4,75	0,64	2,59	0,45	1,13		0,08	0,73
Feathergrass-white wormwood-sheep's fescue. Chestnut	Tops	0,68	0,13	0,50	0,03	0,04		0,01	0,06
	Roots	8,57	0,47	5,39	0,80	1,08		0,07	0,75
Black wormwood. Solonchic	Tops	0,37	0,04	0,12	0,06	0,04		0,01	0,07
	Roots	2,47	0,04	0,89	0,44	0,31		0,13	0,62
Mixed herbage-feathergrass. Meadow-chestnut	Tops	1,90	0,28	0,16	0,05	0,37		0,03	0,78
	Roots	13,08	1,17	6,62	1,62	2,51		0,02	1,84

^aIn the calculations it was assumed that a third of the total roots enters the soil annually in the form of litter.

^bSum of CaO + MgO.

Note: Comma represents decimal point.

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Table 8

Results of total chemical analysis, % of ignited sample

Horizon	Depth, cm	SiO ₂	P ₂ O ₅	Al ₂ O ₃	Fe ₂ O ₃	R ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	MnO
Ordinary, thick, chernozem clay, "Parizhskaya kommuna" kolkhoz, Kokchetav Oblast'											
A	0—10	72,76	0,39	13,62	6,73	20,75	2,97	2,03	2,38	0,79	0,06
A	16—25	71,31	0,38	13,66	6,82	20,88	3,03	1,15	0,73	0,06	
B ₁	35—45	71,27	0,31	13,89	6,27	20,47	3,82	1,42	2,14	0,68	0,06
B ₂	55—65	70,31	0,28	14,84	6,22	21,35	4,41	1,82	2,15	0,83	0,06
C	100—110	68,39	0,18	15,36	5,65	21,48	4,61	2,04	2,11	0,97	0,06
Southern, calcareous, chernozem clay, Novorybinsk sovkhov, Tselinograd Oblast'											
A	0—10	66,45	0,17	13,52	7,09	20,79	6,54	1,93	0,73	1,94	0,03
A	12—22	66,84	0,18	15,61	6,05	21,84	5,81	2,51	1,71	1,29	0,03
B ₁	30—40	64,21	0,23	12,26	7,48	19,98	11,69	1,69	0,87	0,93	0,03
B ₂	60—70	65,49	0,24	14,77	5,96	20,97	8,81	2,46	1,28	1,50	0,03
C	100—110	66,72	0,15	14,38	6,85	21,42	6,85	2,46	1,11	1,65	0,03
Calcareous dark-chestnut clay, "Zhanyspay" sovkhov, Tselinograd Oblast'											
A	0—20	67,32	0,16	15,81	6,20	22,17	6,19	1,81	2,19	0,62	0,12
B ₁	30—40	65,40	0,16	16,15	6,20	22,51	6,90	2,32	1,48	0,50	0,16
B ₂	55—65	64,75	0,18	15,25	6,02	21,95	7,99	2,63	1,91	0,69	0,12
BC	85—95	64,17	0,10	16,35	5,97	22,42	9,09	2,41	1,87	0,78	0,08
C	122—132	63,04	0,12	15,90	6,28	22,33	10,01	2,40	1,24	0,51	0,08

Note: Comma represents decimal point.

source of ash substances is the root system of plants. This agrees with the data of other investigators (1, 7). The root system of virgin vegetation is very branched and reaches a considerable depth. Thus, the roots of feather-grass and sheep's fescue penetrate to a depth of 1.1-1.2 m, while those of steppe alfalfa reach 2 m and more.

Under such conditions nutrients are transported from the lower into the upper horizons and concentrate primarily in the form of organic matter in the upper layer of the soil. Certain ash elements, along with humus and nitrogen, accumulate during the formation of the profile of chernozems and dark-chestnut soils under the influence of grass vegetation. As a result, their total content in the upper horizon increases somewhat as compared to the parent material.

The data in Table 8 show that the upper parts of all the profiles analyzed contain more silica than the parent material, whereby silica accumulates more or less evenly in all the humus horizons of ordinary chernozem, and in the A and B₁ horizons in southern chernozem and dark-chestnut soil. The biological accumulation of phosphoric acid is especially pronounced in ordinary chernozem where its content in the upper horizons is more than double that in the parent material. The maximum accumulation of phosphoric acid in southern calcareous chernozem and calcareous dark-chestnut soil occurs in the horizon with the maximum carbonate concen-

tration, which is associated with the removal of soluble forms of phosphoric acid from the upper soil horizons. The biological accumulation of sesquioxides, and alkali and alkaline earth metals is weak.

In spite of the high total content of nitrogen, phosphorus, and potassium in the soils, they are not readily available to plants, which is attributable to the low content of available forms of these compounds. Repeated determinations showed that the content of easily hydrolyzable nitrogen compounds in virgin soils varies from 9-12 mg/100 g of soil and increases to 17 mg in plowed soils.

This transformation of organic nitrogen into mineral forms occurs under the influence of nitrification and ammonification processes. These processes are weak in virgin soils, and practically no nitrate nitrogen accumulates in them, as was mentioned earlier. In old arable areas, and especially in fallow fields, the amount of nitrates is high. The content of available phosphorus is low in virgin chernozems and dark-chestnut soils (4-2 mg per 100g of soil). The plowing of virgin land increases its availability somewhat, but on the whole its content remains low, 8-10 mg/100 g of soil.

As far as available potassium is concerned, its content in virgin soils is higher, as a rule, than in old arable soils, and in individual cases, reaches a considerable value (75 mg/100 g of soil). The decrease of available potassium in

old arable soils (to 20-40 mg/100 g of soil) is attributable to its uptake by agricultural crops and its removal with the harvest.

As we know, virgin soils are compact and dry and therefore have a low microbiological activity. As a result of plowing the water-physical properties of virgin soils improve, microbiological processes intensify, and the nutritional regime of the soils improves, which creates favorable conditions for the growing of agricultural crops. We studied the physical properties of the soils in cylinders with an undisturbed structure. The results of these studies are presented in Table 9.

The data show that the plowing of virgin soils is accompanied by a change in the structure of the plowed horizon (0-20 cm), namely: bulk density decreases, and the total porosity and full water capacity increase. The physical properties of soils depend to a great extent on the content of water-stable aggregates in them (Table 10).

An analysis of the data in Table 10 shows that virgin chernozems and dark-chestnut soils contain considerably more water-stable aggregates larger than 0.25 mm in diameter, than the corresponding old arable soils. In addition to quantitative differences in the aggregate composition of virgin and old arable soils there are quantitative differences which consist in that aggregates 1-3 mm in diameter predominate in virgin soils, while aggregates from 0.25-1 mm in diameter predominate in old arable soils.

The soil structure is destroyed most rapidly in the first few years after the plowing of virgin land, later this process slows down as the aggregates become smaller. This is why the amount of water-stable aggregates larger than 0.25 mm in diameter does not fall below 50% after 6-10 and even 50 years.

An important characteristic of the agricultural properties of soils is water permeability. We studied water permeability with the Shayn device

Table 9
Water-physical properties of virgin and old arable soils

Soil	Depth, cm	Bulk density, g/cm ²		Total porosity, %		Total water capacity	
		Virgin land	Old arable land	Virgin land	Old arable land	Virgin land	Old arable land
Ordinary chernozem	0-20	1,01	1,05	60,52	62,80	59,61	58,38
	20-30	1,27	1,07	52,88	62,86	41,67	52,27
	30-40	1,30	1,27	48,89	52,47	38,89	51,85
Southern chernozem	0-10	1,09	0,94	54,98	68,51	53,66	65,33
	10-20	1,18	1,04	59,88	69,38	52,71	67,67
	35-45	1,33	1,18	47,72	65,46	45,63	66,96
Dark-chestnut	0-10	1,08	0,97	68,23	73,87	63,23	70,30
	10-20	1,26	1,09	56,35	71,73	44,45	65,63
	20-30	1,39	1,17	53,32	61,44	38,88	52,45

Note: Comma represents decimal point.

Table 10

Content of water-stable aggregates in ordinary chernozem, southern chernozem, and dark-chestnut soil in the layer from 0-20 cm, % (determined according to the Savvinov method)

Soil	Land use	Aggregate diameter, mm				
		5	5-3	3-1	1-0,25	>0,25
Ordinary chernozem	Virgin land	14,77	13,62	30,25	22,15	80,79
	6 years after plowing	5,62	1,05	13,50	34,32	54,49
	10 years after plowing	2,25	5,82	17,17	29,95	55,19
Southern chernozem	Virgin land	22,17	8,14	19,14	15,15	64,60
	About 50-year old arable land	11,88	5,73	11,46	24,93	54,0
Dark-chestnut	Virgin land	19,90	9,50	15,76	24,0	69,16
	5 years after plowing	8,14	4,79	15,19	31,61	59,73

Note: Comma represents decimal point.

Table 11

Percolation rate of water, mm/hr per 1 cm³

Land use	Depth, cm	Amount of percolating water						Total in 6 hours
		1hr	2hr	3hr	4hr	5hr	6hr	
Ordinary fine clay loam chernozem								
Virgin land	0—20	24,8	25,8	24,8	24,2	24,0	23,0	146,6
	20—30	5,40	5,3	5,5	5,40	5,3	5,3	32,1
About 100-year old arable land	0—20	59,80	54,0	46,6	43,8	43,4	42,6	286,6
	20—30	187,2	172,5	158,7	137,7	138,8	135,6	930,5
	30—40	17,9	11,8	12,6	12,3	11,1	10,6	77,3
Southern fine clay loam chernozem, solonetz								
Virgin land	0—10	26,5	22,4	23,4	23,8	23,8	23,0	142,9
	10—20	0,8	0,4	0,5	0,6	0,4	0,4	3,1
	35—45	0,5	0,3	0,2	0,2	0,2	0,2	1,6
About 50-year old arable land	0—10	42,9	35,4	32,2	30,0	28,0	28,8	197,0
	10—20	54,4	56,8	46,8	44,0	41,0	38,6	283,4
	20—30	11,6	7,0	5,4	4,8	5,1	5,4	39,3
Dark-chestnut fine clay loam								
Virgin land	0—10	30,4	31,6	32,3	31,6	30,6	29,4	185,4
	10—20	24,0	25,0	24,5	24,0	24,3	23,7	145,5
	20—30	4,8	5,0	4,9	4,5	5,0	5,4	29,6
5 years of use after plowing virgin land	0—10	280,6	267,0	262,4	264,4	265,0	268,6	1608,0
	10—20	50,8	52,2	50,9	44,2	41,6	42,6	251,6
	20—30	5,6	4,9	4,9	5,2	5,4	5,4	31,4

Note: Comma represents decimal point.

as modified by I. D. Gromyko¹ in soil samples with an undisturbed structure. As we can see from Table 11, the percolation rate in virgin soils is lower than in old arable soils, which is attributable to their more compact structure. The water permeability of virgin soils decreases sharply with depth along the soil profile, especially at the transition from the 0 to 10 cm layer to the 10-20 cm layer, while in old arable soils the water permeability in the 10-20 cm layer is often higher than in the layer from 0-10 cm. This indicates that the upper layer compacts more with time under the influence of precipitation, agricultural implements, and other factors than the lower-lying 10-20 cm layer. The subplow layer from 20-30 cm in chernozems and chestnut soil has a low permeability as a rule. As a result it often serves as a water barrier and interferes with the free percolation of moisture into the lower-lying soil horizons. Therefore it is necessary here to plow the subplow layer. In contrast to old arable soils, the water permeability of the upper layer of virgin soils remained practically unchanged in the 6 hours of observation, which points to the great water stability of aggregates.

Conclusions

1. Virgin chernozem and dark-chestnut soils, formed under the influence of meadow-steppe and steppe vegetation with a dense, branched, and deep root system, contain respectively 250-500 cнtr/ha and 200-300 cнtr/ha of root residues in the upper meter.

2. The natural structure of virgin chernozems and dark-chestnut soils is unfavorable to cultivated plants. A change in the structure of the upper layer of virgin soils by deep plowing and subsequent agricultural practices promotes the formation of favorable conditions for the development of agricultural crops.

3. After virgin land is plowed and used for annual agricultural crops for a long time, its content of root residues, humus, and nitrogen decreases and the stability of its structure degenerates. At the same time microbiological activity and porosity increase, and water permeability improves. These changes are especially pronounced in chernozems in the first 6-8 years and in dark-chestnut soils in the first 4-6 years after the plowing of virgin land, i.e., during the period when the organic residues of virgin vegetation decompose intensely.

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MAINTENANCE AND INCREASE OF THE PRODUCTIVITY OF FLOOD-PLAIN SOILS IN THE NON-CHERNOZEM ZONE

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All the resolutions of the Party and Agricultural Management, especially beginning with the historic September 1953 Plenum of the Communist Party of the USSR, specify the need of properly reclaiming and utilizing flood-plain lands, especially for vegetable and various forage crops.

In his report to the February 1954 Plenum of the Communist Party of the USSR, N. S. Khrushchev said: "The reclamation of flood-plain lands, bogs, and peatbeds will make it possible to utilize agriculturally very fertile lands on which vegetables and other crops could be grown near cities and industrial centers" (p. 15).

In conformity with these instructions more and more flood-plain lands are being used for agricultures. In the Moscow Oblast' alone more than 30,000 hectares out of the 120,000 hectares occupied by flood-plain lands have been plowed. The reclamation of the flood plains of the Moskva, Oka, Klyaz'ma, Yzhroma, and other rivers is being stepped up. A special resolution of the Communist Party of the USSR and the Council of Ministers of the USSR of November 2, 1958 calls for the establishment of 35 specialized sovkhozes in the Moscow Oblast' for the growing of potatoes and vegetables. A large part of these sovkhozes is located on flood-plain land. They include the "Ramenskiy" sovkhoz in which we conducted certain of our investigations. The proper reclamation of flood-plain lands requires a thorough study of the characteristics of flood-plain soils, their evolution and regime of soil formation. An important task is not only to utilize the wealth of this natural "reservoir" to the maximum, but to increase it reasonably.

As practice shows, the plowing of flood-plain land by man and a number of meliorative and agricultural measures lead in time to a considerable change in the direction of the soil-formation process. Under these conditions the magnitude and nature of the biological cycle of plant nutrients is disturbed first of all. The change of natural meadows to various agricultural crops, primarily row crops, which require especially thorough and frequent soil tillage, leads to a rather rapid destruction of the soil structure and the degradation of its hydrological and aeration properties, whereby

the rhythm and nature of the activity of microflora change.

A thorough and comprehensive study of soil formation in flood plains requires not only soil-geographical investigations, but also permanent observations on the dynamics of soil processes.

The high potential fertility of flood-plain soils, especially those which are not waterlogged, can be explained only by the deposition of silt that is rich in nutrients. An important fact distinguishing soil formation in flood plains from that on watersheds is the intensity of the entire complex of soil processes in a flood plain and, first of all, the high biogenity of soils under natural meadow vegetation. This is manifested in the rapidity and intensity of the biological cycle of nitrogen and ash elements, in the large accumulation of organic residues, intense microbiological activity, the amount of soil fauna, and a number of other factors.

The annual plant yield differs in natural meadows in various parts of a flood plain, but even if the grass is cut twice in the meadows, a reliable and constant source of organic matter always remains in the soil in the form of the root system of annual and perennial meadow grasses.

Our assessment of the biological mass on sod-meadow soils in the Faustov broad flood plain of the Moscow River (Stalin kolkhoz, Vinogradov rayon), as well as on the humic-peat-gley soils of the Ramenskoye broad plain ("Ramenskiy" sovkhoz), showed that the vegetable yields vary greatly depending on the characteristics of the vegetation. As we can see from the data in Table 1, the vegetation of natural meadows creates a great amount of vegetables, varying from 50-60 cntr/ha of dry substance. Similar yields are obtained from sown perennial (timothy) and annual (Sudan grass) grasses. Consequently, when a virgin meadow is plowed and the natural vegetation is replaced by sown grasses there is almost no noticeable difference in the magnitude of the straw yields. However, when row crops, especially vegetables, are used in crop rotation, the yield of those plant parts which are used by man increases considerably. Thus, 3 times more of the biological mass of organic substances is removed in the harvest of cabbage than in the harvest of grass.

Table 1

Yield of various plants-on flood-plain soils (weight of air-dry mass, cntr/ha)

Soil	Land use	Tops	Roots
Sod-meadow, Stalin kolkhoz	Timothy-oat meadow	50,0	160,0
	Sown timothy	50,0	115,0
	Sudan grass	65,50	49,0
	Aftermath of natural meadow	13,70	153,0
	Aftermath of timothy	12,35	110,0
	Cabbage	180,0	11,0
Humic-peaty-gley, "Ramenskiy" sov-khoz	Hair grass meadow	60,0	260,0
	Meadow grass	37,5	168,0
	Cabbage	185,0	12,0

Note: Comma represents decimal point.

If we examine the root mass, we will see that it is greatest under natural meadows (from 160-260 cntr/ha). A slightly smaller root mass is produced by sown perennial grasses (110-115 cntr/ha), and an insignificant mass, by white cabbage (11 cntr/ha).

Thus, if the ratio between the roots and tops of perennial grasses is 1:3 and 1:4, for annual grasses it is about 1:1, while for cabbage it is 16:1 and 15:1.

When assessing the biological mass of the grass tops we must consider that after the first mowing there is considerable aftermath in meadows at the end of the growing period, which becomes covered with snow and is one of the sources of organic matter to the soil. Thus it is quite evident that virgin flood-plain soils, which form under conditions of a high annual supply of organic residues, have a large amount of nutrients. The cutting of meadow vegetation is amply compensated for by the remaining parts of plants (roots, aftermath), which release on mineralizing a large amount of nitrogen, phosphorus, potassium, and other nutrients. We can make the same conclusions with respect to sown perennial grasses.

A different picture is observed when a flood plain is used for growing vegetables, especially cabbage.

As we can see from Table 1, the harvest of cabbage exceeds the parts of plants remaining in the soil by 15-16 times. If a rather large amount of organic substances, produced by meadow vegetation, remains in the soil during the first year after plowing a flood plain, later, when the soil is tilled and cultivated intensely, favorable conditions are created from the rapid mineralization of the organic substance and the humus content in the plowed layer of sod-meadow soils decreases. Under these conditions the removal of the organic mass produced by cabbage is not compensated for by the biological mass remaining in the soil. Since cabbage is a crop which demands

the presence of organic substances, we should consider whether it will be expedient to introduce perennial grasses into vegetable crop rotation.

Changes in the nature of the vegetation of flood-plain soils not only affect the quantity of the biological mass removed and accumulated, but also lead to a rather sharp change in the direction of soil processes from the qualitative point of view. As we have already mentioned in one of our earlier papers (3), each type of vegetation is characterized by individual differences in ash composition and nitrogen content. Consequently, the replacement of one type of vegetation by another will lead to a change in the nature and magnitude of the biological cycle.

Processing from the analysis of the ash composition of plants (3) and the assessment of the biological mass, we tried to establish the magnitude of the accumulation and removal of nutrients from flood-plain soils by various plants (Table 2). As we can see from a simple comparison of the data, after a single harvest of various plants, the largest amount of the major nutrients is removed from the soil by cabbage. According to Edelshteyn (8), cabbage belongs to that group of agricultural crops which removes the highest amount of nutrients, primarily nitrogen and potassium.

Only the removal of potassium is not compensated for by its amounts remaining in the roots and aftermath of mixed herbage-grass and hair grass meadows after 2 mowings. The amount of elements fixed in the soil by the root system of cabbage is very small.

It is evident that when flood-plain soils are reclaimed for vegetable crops, the sod process, inherent to flood-plain under natural meadows, will weaken. This will require the addition of a large amount of organic and mineral fertilizers to the soil, and may be the introduction of perennial grasses into crop rotation in certain areas.

FLOOD-PLAIN SOILS

Table 2

Removal and accumulation of nitrogen and certin ash elements in various vegetation on flood-plain soils, kg/ha of absolutely dry substance

Land use	N	P	K	Ca
Removed with the harvest				
Timothy-oat meadow	90	14	103	13
Hair grass meadow	140	2	50	45
Sown timothy	65	10	80	11
Cabbage	546	75	433	312
Left in the soil ^a				
Timothy-oat meadow	229	53	129	81
Hair grass meadow	326	4	68	347
Sown timothy	180	39	116	58
Cabbage	49	7	39	28

^aRoots + aftermath

A not less important index of the biogenity of soils is the activity of various groups of microorganisms.

When studying the microflora of soils in the Klyaz'ma River valley (Khimki rayon, Moscow Oblast'), I. P. Bab'yeva¹ found that flood-plain soils are distinguished by a higher biogenity than the sod-podzolic soils of the watershed area (Table 3). If we compare various soils we can see clearly that meadow flood-

plain soil under a foxtail grass — hair grass meadow and the upper horizon of peat-gley soil under a birch forest on the terrace-side of a flood-plain have the highest biogenity. In fact, from May to December 1955 the maximum number of bacteria was found in the foregoing flood-plain soils, and the minimum in the sod-podzolic soil of the original bank. The largest amount of fungi was found in soils in the forest or in soils where there was recently a forest, while the least amount was found in the meadow soil of the flood plain.

¹The microbiological data are presented with the kind permission of I. P. Bab'yeva.

It must be noted that the number of micro-

Table 3

Fluctuations in the number of microflora in soils of the Klyaz'ma River valley (Chashnikovo rayon) from May to December 1955, in thousands per 1 g of dry soil

Plot No.	Soil	Depth, cm	Bacteria			Fungi	Actino-mycetes
			Beef-pep-tone-agar	Chapek medium	Ashby medium		
I	Flood-plain sod-podzolic under a forest on a bank near the river	0—5	132—2132	453—2210	437—3220	6—37	16—209
		14—20	76—142	238—2000	266—1090	4—17	1—37
II	Meadow under a foxtail-hair grass meadow in the central flood plain	0—5	514—1312	1253—2124	933—4500	3—17	18—675
		18—25	217—640	483—1345	876—2087	2—7	19—164
IV	Peaty-gley under a birch forest on the terrace of the flood plain	0—20	700—3075	751—2600	1102—4262	3—54	62—975
VI	Sod moderately-podzolic under a mixed forest on the original bank	0—5	244—353	523—1333	525—2666	10—30	2—330
		15—25	33—103	45—278	30—454	5—11	0—56

Table 4

Number of microorganisms along the soil profile in the second decade of August 1955, in thousands per 1 g of dry soil

Plot No.	Soil	Depth, cm	Bacteria			Fungi	Actino-myces
			Beef-peptone-agar	Chapek medium	Ashby medium		
VI	Sod-podzolic on the original bank under a mixed forest	0—5	244	523	525	10,8	20
		15—25	33	45	30	5,2	0
		55—65	26	57	51	0,2	0
II	Meadow flood-plain under a foxtail — hair grass meadow	0—5	590	1540	2980	3	675
		18—25	480	780	978	3,3	102
		50—60	896	1378	2464	2,6	14,3

Note: Comma represents decimal point.

organisms decreases very gradually with depth along the profile of meadow flood-plain soils (Table 4), and sometimes even increases in the buried horizons. At the same time all life in sod-podzolic soil is concentrated in the very upper horizons, immediately under the forest litter.

An analysis of growth glasses from these soils, made in 1956, basically confirmed the results obtained from the assessment of the microflora by the inoculation method. The largest bacterical growth was found in the meadow and peat soils along the terrace. Fungi covered most densely those glasses which were placed in the forest soils of the watershed and along the river of the flood plain.

cellulose in the soils studied, made by the method of soil aggregates in a Hutchinson medium and by placing slide glasses with filter paper in the soil, showed that the decomposition of cellulose was most intense in meadow flood-plain soils; it was weaker in the peat-gley soils along the terraced flood plain and podzolized soils along the river flood plain under the forest, and almost unnoticeable in the sod-podzolic soils of the watershed (Table 5).

The study of the microflora in the Klyaz'ma River valley in the Kovrov rayon, Vladimir Oblast', also showed that flood-plain soils have a higher biogenity (especially where bacteria are concerned) than the podzolic soils of the original bank (1).

The study of the microbial decomposition of

The drained peat-humus-gley soils of the

Table 5

Decomposition of cellulose by microorganisms in soils of the Klyaz'ma River valley (experiment from June 15-26, 1956 with glasses with paper placed in the soil)

Plot No.	Soil	Depth, cm	Intensity of cellulose decomposition
I	Sod-podzolic under a mixed forest along the riverbank	3—5 18—20	There are no areas of complete decomposition, the paper became only slightly thinner
II	Meadow soil under a foxtail — hair grass meadow	3—5 18—20	Intense decomposition of the paper, hardly noticeable remains of the paper are found only in certain places
IV	Peaty-gley under a birch forest along the terrace of the depression	3—5 18—20	Small areas of decomposed paper, generally the paper is whole
VI	Sod-moderately — podzolic soil under a mixed forest on the watershed	3—5 18—20	No decomposition, paper remained unchanged

Moscow River flood plain in the sovkhos "Ramenskoye" proved to be highly biogenic. In spite of considerable fluctuations during the growing period of 1959, the amount of bacteria found in beef-peptone-agar reached 11 million and in the synthetic medium of Chapek, 186 million per gram of absolutely dry soil.

One of the indications of the high biogeneity of flood-plain soils is also the large number of invertebrate animals, especially earthworms, inhabiting them. Soil faunistic observations in the Klyaz'ma River flood plain showed that the number of earthworms in flood-plain soils under meadows reaches 350-450 per 1 m², while there are only 90-140 per 1 m² in the sod-podzolic soils under the forest on the original bank (2).

The well-developed root system of meadow grasses on flood-plain soils, the large amount of organic substances in them, and the intense life activity of animals and microorganisms inhabiting the soil result in the good granular structure of flood-plain soils. The preservation of the agriculturally valuable structure of flood-plain soils, as one of the most important conditions for their fertility, also deserves a certain attention in relation to the plowing and reclamation of flood plains for row crops. As our observations showed, the sod-meadow soils of virgin areas in the Moscow River flood plain have a pronounced fine granular structure, which is characteristic for the entire root zone.

The original soil of a mixed herbage-grass meadow is characterized by a high content of agriculturally valuable and water-stable aggregates (10-1 mm in diameter), reaching

43%-46% during the flowering period of the plants (July). The amount of the fraction <0.25 mm in diameter is 37%-40%.

As the investigations of Rudina (4) showed, the content of aggregates 10-1 mm in diameter increases considerably under natural meadow vegetation from the beginning to the end of the growing period (to 54%). At the same time the content of aggregates <0.25 mm in diameter decreases sharply (from 41% to 24%). Thus, the positive role of the root system of grasses of a virgin meadow in the creation of the soil structure is clearly defined.

Plowing of flood-plain soils and the destruction of the sod disturb the natural processes of structure formation and the effect of mechanical cultivation implements begins to be felt, especially after the repeated cultivation of various crops. Such crops as cabbage, beet, potatoes, onions, carrots, etc. which require thorough soil cultivation and do not have an extensive root system, do not promote the preservation of the original structure of flood-plain soils. Our observations in the fields of the Stalin kolkhoz in Vinogradov rayon, Moscow Oblast', showed that the constant cultivation of row crops every year leads to the considerable destruction of the structure of the plowed horizon of flood-plain soils at the end of the growing period, and to the increase in the content of aggregates <0.25 mm in diameter:

Amount of aggregates <0.25 mm in diameter under various crops, %

	July	October
Potatoes (after cabbage)	51.0	53.5
Beets (after sunflower)	58.0	65.5

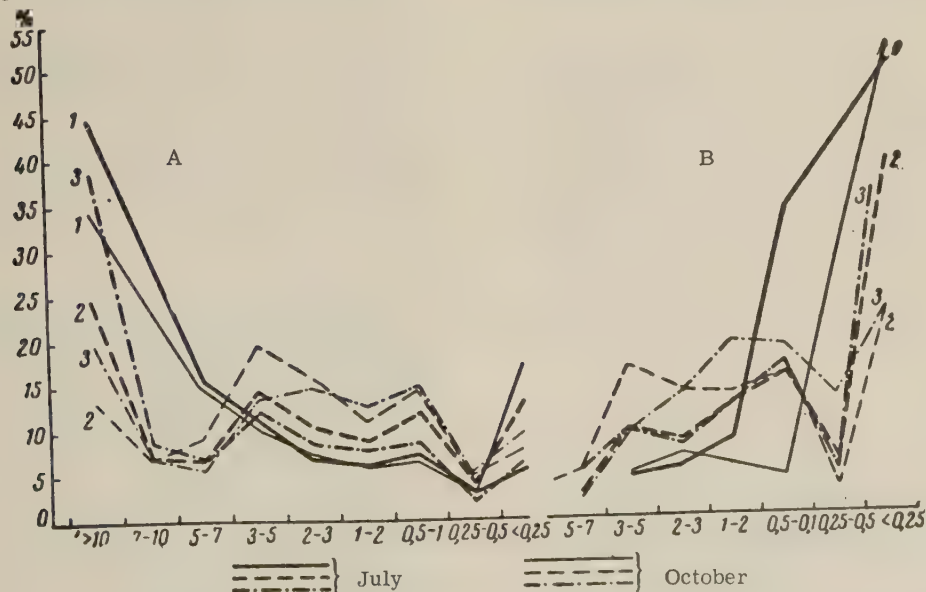


Fig. 1. - Structural composition of sod-meadow soils of the Moscow River flood plain 1955 (according to the data of L.A. Rudina)
A - dry sieving; B - wet sieving. 1 - potatoes; 2 - natural meadow; 3 - timothy.

According to the data of Rudina (4), plowing of the meadow and the growing of cabbage in this area leads to a certain decrease in agriculturally valuable aggregates (from 32.0% to 27.0%) and to an increase in the amount of aggregates < 0.25 mm in diameter (from 44.5% to 52.5%) as early as in the first year. In the old plowed area the content of aggregates 10-1 mm in diameter decreased from 22.0% in July to 8.0% in October.

Thus, the constant growing of row crops may lead to a certain loss in structure of flood-plain soils during a relatively short period of time, which can result in the degradation of the moisture-aeration and nutritional regimes of these soils. It is quite evident that structureless soils will have a much lower erosion resistance and be more easily eroded during floods and then become silted after the water recedes. Measures must be taken to avoid such an undesirable process.

The most expedient in this case is the constant addition of organic and mineral fertilizers, the introduction of perennial grasses into crop rotation in certain places, the establishment of forest shelterbelts along the river of the flood plain, and other measures. As experience shows, the aggregating effect of the root system of sown timothy is almost as good as that of the grass roots of a natural meadow, resulting in the average increase of aggregates from 10-1 mm in diameter in the plowed horizon of 15%-16% (Fig. 1) during the growing period, and a 12% decrease of aggregates < 0.25 mm in diameter. Moreover, in addition to having an aggregating effect, perennial grasses leave after them a tremendous amount of nutrients in the roots and crop residues (Table 1), which undoubtedly also promotes the increase of the fertility of the given soils.

We recommend that perennial grasses be sown not only on the sod-meadow soils of the central flood plain, but also along the river of the flood plain and, especially, along the drained terrace, the soil of which includes peaty soils to various degrees. Skrynnikova (5) reports that the soil scientists of the German Democratic Republic find it necessary, on the basis of long-term observations, to sow perennial grasses 3-4 years after peaty-bog soils have been reclaimed for vegetable, grain, and row crops and leave them for 7 years. We find similar recommendations in other papers (6, 7).

Conclusions

1. The plowing of flood-plain soils and their subsequent utilization for agricultural crops, especially row crops, changes the regime of soil formation in the flood plain considerably, which requires its regulation.

In order to maintain and increase the productivity of flood-plain soils during their

agricultural utilization it is necessary to develop a special system of soil tillage, which would take into account the peculiarities of soil formation in the flood plains of rivers in the non-chernozem zone.

2. The most important elements of the agricultural system on flood-plain soils must be:

- a) specialized crop rotation, producing high and consistent crop yields on flood-plain soils and promoting the aggregation of soils and the accumulation of humus and nutrients in them;

- b) a fertilization and tillage system taking into account the characteristic properties of the soils and agricultural crops;

- c) the proper distribution of land uses in river valleys (fields, meadows, forest plantations), which would prevent the development of erosion processes in the flood plain.

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BRIEF RESULTS OF A SITE EVALUATION OF SOILS IN KOLKHOZES OF THE TOMSK OBLAST'

N. F. TYUMENTSEV

The soils of all the kolkhozes in the Tomsk Oblast' were studied from 1947 to 1959. The results of this work which are presented in the form of large-scale soil maps and sketches, give a clear idea of local natural conditions and serve as the basis for the solution of important problems in the planning and conduct of agricultural work.

The work conducted in the USSR since 1955 on the site quality of soils increases the practical value of the results of soil investigations and makes it possible to use them with even greater confidence in agricultural practice.

The first steps in the work on the site quality of soils: the study of the literature, and the experimental, methodological development of various phases of the problem — have shown that its success depends entirely on the correct solution of 3 related problems: 1) the establishment of the principles of the assessment or system of determining the quality of soils; 2) the development of a method and site evaluation of the soils (lands) of individual farms, rayons, and Oblast's, and 3) the practical application of the results of this work by agricultural enterprises. Such a methodological approach makes it possible to establish the sequence of the work, uncover and eliminate the shortcomings of the site quality method, and establish it on a more practically expedient basis.

Let us examine the major aspects of the accomplished work. As the literature was studied it was found that there were two directions in the development of methods for the qualitative evaluation of soils: economical — according to monetary gains or yields, and soil-genetic, based on the properties of the soils.

In examining soil properties in relation to the yield of agricultural crops on them, we obtain a picture of the fertility and productivity of the soil.

Only individual indices of a given soil group are often taken into consideration: the thickness of the humus horizon, the percentage of humus, the reaction of the medium, the sum of adsorbed cations, etc., on the basis of which the site quality of soils is then evaluated.

As we became acquainted with the various methods of qualitatively evaluating soils we concluded that the most correct principles are those established by V. V. Dokuchayev and V. M. Sibirtsev. Dokuchayev considered the "natural capacity" of soils, i. e., the internal properties of soil which characterize its fertility, as most important when evaluating soils.

We took the genetic principle as the basis for the development of the site quality scale.

The initial data for the site quality evaluation of local soils are the genetic soil group in the broad sense of the word with all its amount of humus, nitrogen, and phosphorus in the layers from 0-20 cm, 0-50 cm, and 0-100 cm, in metric tons per hectare. The concept of soil group includes the combination of its various properties, while the amounts of humus, nitrogen, and phosphorus reflect the chemical and physical basis of fertility.

The available material made it possible to calculate and compare the most widespread soil groups and subgroups in the Tomsk Oblast'. We determined: leached chernozems, dark-gray, gray, and light gray forest soils, sod-podzolic, and podzolic soils, among which we selected soils similar in texture — medium clay loam. As a standard we used leached chernozem as the most fertile soil in the Tomsk Oblast'. The major properties of this chernozem are shown in Table 1.

These data for leached chernozem and similar data for other soils served as the basis for the calculation of the amounts of humus, nitrogen, and phosphorus in metric tons per hectare (Table 2).

We must explain why we took the average of 3 thicknesses as the initial value. The main root mass of agricultural plants is distributed in the layer from 0-20 cm, but many roots penetrate to a depth of 50 cm, and some to a depth of 100 cm, using the moisture and certain nutrients available there. If we should base only the amount in the layer from 0-20 cm, the role of the lower soil layers will not be reflected, while if we take the amount in only one of the remaining two layers, the special importance of the layer from 0-20 cm for the life of the soil and plants

Table 1

Properties of clay loam moderately thick leached chernozem

Horizon and its depth, cm	Sampling depth, cm	Total content, %			Bulk density, g/cm ³	Particles <0.01 mm in diameter, %
		Humus	Nitrogen	Phosphorus		
A _{plw} 0—23	0—15	9,76	0,49	0,179	0,92	52,7
A ₁ 23—38	24—34	7,50	0,38	0,160	1,00	55,8
AB 38—50	40—50	4,11	0,20	0,120	1,10	58,1
B ₁ 50—70	55—60	2,52	0,14	0,092	1,20	59,3
B ₂ 70—80	70—80	1,09	0,07	0,074	1,20	60,7
BC 80—100	90—100	0,90	0,06	0,070	1,30	61,3

Note: Comma represents decimal point.

Table 2

Humus, nitrogen, and phosphorous content in the basic soil varieties, metric tons/ha

Soil	Layers, cm								
	Humus			Nitrogen			Phosphorus		
	0—100	0—50	0—20	0—100	0—50	0—20	0—100	0—50	0—20
Leached chernozem	471,3	374,3	179,6	24,5	18,7	9,0	12,7	7,8	3,3
Dark-gray forest	505,8	429,2	190,5	28,8	23,7	10,3	12,4	7,9	3,6
Gray forest	321,0	262,0	154,9	19,1	14,2	8,2	10,4	6,4	3,5
Sod-podzolic	157,8	112,0	60,9	11,2	7,0	3,4	10,3	5,2	2,3
Podzolic	125,0	78,0	45,2	7,8	4,5	2,4	5,0	3,5	1,8

Note: Comma represents decimal point.

will be lost.

We expressed the total content of humus, nitrogen, and phosphorus in the soils compared in percentages of the amount of these substances in the leached chernozem, taking the arithmetic means of these data for 3 thicknesses (0-20 cm, 0-50 cm, and 0-100 cm). Thus we obtained a basis for establishing the index value for each soil.

To establish the initial index value we included in our calculations all average grain crop yields in kolkhozes with typical soils for 3 years, winter rye for 2 years, and spring wheat in geographical experiments for 2 years. In this case we considered productivity as the expression of the biological properties of the soil. Since the amounts of humus, nitrogen and phosphorus accumulate as a result of many centuries of crop yields they essentially characterize many centuries of productivity fixed naturally in soil properties.

Thus we established initial index values for soils suitable for cultivation. Sod-meadow flood-plain soils were evaluated only on the basis of their humus content. Bog soils were evaluated in the same manner.

During the site quality study the soils were

grouped on the basis of their present state of cultivation. All the soils were combined into 3 groups. I. Soils suitable for every kind of agricultural use. II. Soils suitable for growing forage crops. III. Soils to be reclaimed. The grouping was based on the productive properties of the soils — their suitability or non-suitability for growing one or the other crop.

The soils of group I are suitable for growing plants inherent to the given soil-climatic zone, from trees to various cultivated and wild herbaceous plants. These soils can be utilized for various agricultural land uses — fields, hay fields, pastures, orchards, and forests. The most important land used at present are fields on which the most important product — grain — can be grown, as well as various types of forage and industrial crops.

The crop yield is higher on leached chernozem than on podzolic soil; nevertheless, both soils can be used to grow the same crops but of different varieties. It would hardly be necessary to divide the groups into subgroups, since soils do not differ that much on one and the same farm, e.g., chernozem and podzolic soil. If it were necessary, soil varieties may serve as subgroups.

Soils of group II have a limited agricultural

application and serve for growing forage for hay or as pastures for cattle and horses. Their use for growing agricultural crops would require additional expenditures on melioration. This group includes sod-meadow soils in river flood plains, which are usually inundated during spring floods. Other soils which are unsuitable for fields but suitable for hay and forage may be included in this group, such as the complex soils of slopes.

Group III combines potentially fertile humus-peat and peat-bog soils, which are as yet unsuitable for agricultural use.

As a result of the calculation of index values for each soil variety and their productivity groups, we constructed the main index scale (Table 3).

The scale needs further elaboration, especially with respect to soils of groups II and III, but it can be used as it is as a basis for evaluating soil.

In developing the index scale we selected the most typical soils, whereas in nature there are many deviations from the typical average genetic representatives of soils in which one or the other of their properties is intensified or weakened. Therefore, in our site quality studies we had to introduce corrections for the deviations from the typical "internal soil properties," texture, the thickness of the humus layer, the degree of water-logging, and stage of cultivation. Without substantiating the corrections, we present the coefficients used in Table 4.

Where several corrections are needed, their product will give the general correction coefficient for the internal soil properties.

When the correction for texture is used, we took into account the specific resistance of the soil. The rest of the corrections were made by calculation. The corrections need further elaboration.

After the corrections are added we obtain a calculated index which is conditionally accurate for the soil of a given area or field in conformity with the formula

$$I_c = I \cdot C_i$$

where I_c is the calculated index, I is the initial index, and C_i is the correction coefficient for the internal properties of the soil. The development of the method of measuring the quality of soil is complete after the index values have been calculated. This is the basis for the site quality evaluation of the soil in an entire farm.

The site quality of the farm land is described by the formula:

$$I_f = \left(\frac{I_{c1}A_1 + I_{c2}A_2 + \dots + I_{cN}A_N}{R} \right) \cdot C_1,$$

where I_f is the final average weighed index value of soil per 1 ha; I_c is the calculated index; A is the area covered by the soil group (subgroup) being evaluated; R is the total area of the farm land; and C_1 is the correction coefficient for relief and contour, called "local natural conditions."

The contour and relief are determined from land assessment data and from evaluation during field soil surveys. These data were analyzed in the Tomsk Oblast' by a team of specialists from the Regional Agricultural Administration to determine output norms for tractors and combines and establish norms for

Table 3

Basic evaluation scale for the soils of the Tomsk Oblast'

Soil	Initial index values
Group I. Soils suitable for any agricultural use	
Leached chernozem	100
Dark-gray forest	99
Gray forest	78
Light-gray forest	67
Sod-podzolic	52
Podzolic	28
Group II. Soils suitable for forage crops	
Sod-meadow soil in southern regions	73
Sod-meadow soil in northern regions	43
Group III. Soils needing melioration	
Drained peat-bog	100
Drained humus-bog	100

Table 4

Corrected coefficients for the internal properties of soil

Corrections for the properties	Coefficient
Texture	
Fine clay loam and clay	0.9
Sandy loam	0.9
Thickness of the humus layer	
Shallow (up to 16 cm)	0.8
Moderately thick (16-18 cm)	0.9
Degree of water-logging	
Severe, soil is wet, peat	0.1
Gleyey, ground water at a depth of 75-100 cm	0.6
Gleyey B horizon, ground water at a depth of 100 cm	0.7
Gleyey C horizon, ground water below 100 cm	0.8
State of cultivation	
Soils of crop rotations	1.1
Systematically fertilized soils under grass arable crop rotation	1.3
Fertilized soils of truck gardens, orchards, and reclaimed crop rotations along the farms	1.9

their fuel consumption. Taking 3-year average statistical data on the output of tractors and combines, we determined corrected coefficients for each group of complex local natural conditions. They are presented in Table 5.

Having these data it was easy to calculate the average index value for the soil of each farm. This is now being done during the compilation of summary reports on soil investigations in kolkhozes and sovkhoses. After the work on the qualitative evaluation of the soils of individual farms is completed, a summarized site quality record is made in the manner shown in Table 6.

The results of the site quality study are used to determine to which of 9 categories the land of a farm belongs. The first category is the highest, the ninth, the lowest, with 10 points between categories. Those lands which have 91-100 points belong to the first category, those which have 11-20 points, to the ninth.

A site quality record also calls for the calculation of the weighted average index value for productivity groups and for all the land uses on each farm, administrative and natural regions, as well as subzones, zones, and the entire Oblast'. This is the end of the qualitative evaluation of individual farms and administrative regions.

When a site quality study of soil is completed the question arises as to how to present its results in the most intelligible and convenient form for use by regional and local organizations and directly by kolkhozes and sovkhoses. This purpose is served by site quality records, diagrams of the structure and quality evaluation of soils, and site quality soil maps of kolkhozes and sovkhoses within a region or Oblast'.

Such documents were compiled from 291 farms and 20 rayons of the Tomsk Oblast' as of January 1, 1960.

The results obtained show substantial differences between the natural conditions of subzones, rayons, and kolkhozes. A knowledge of these differences makes it possible to differentiate agricultural management: specialize, establish production norms, plan procurements, determine the system of agriculture, establish wage norms, supply machines and agricultural implements, etc. Thus, as a result of the site quality study of the soil in kolkhozes, the differences between the rayons of the Tomsk Oblast', shown in Table 7, have been established.

An index value has been assigned to each subzone, rayon, and kolkhoz, and the soils have been grouped according to productivity.

The results of a site quality study of soil are best represented in the form of diagrams as shown in Figure 1 for the subzones of the Oblast' and in Figure 2 for rayons located in the subzone of sod-podzolic soils.

As we can see from Table 7 and Figures 1 and 2, the natural conditions are rather varied in subzones and rayons. Thus, kolkhoz land in the Shegar rayon has 5 different categories, while in the Kozhevnikovo, Tugan, Tomsk, and Pyshkino-Troitsk rayons, there are 4 categories, etc. In the southern subzone kolkhozes of almost every category are found except category IX, while the majority of the farms have categories IV, V, and VI. In the sod-podzolic soil subzone there are no kolkhozes of category II and III; they are mostly of category VI and VII. The number of kolkhozes of category VIII increases here sharply as compared to the subzone with predominantly

Table 5
Corrections for local natural conditions

Com-plex-ity group	No. of tractor sta.	Output per season as reduced to 1 unit				Corrected coefficients	
		15 h.p. tractor		Combine			Aver. %
		hec-tare	%	hec-tare	%		
For contours							
1	5	558	100	311	100	100	1,0
2	14	475	85	288	92,5	88,5	0,9
3	7	452	81	263	81	81	0,8
For relief							
1	2	536	100	306	100	100	1,
2	14	506	94	288	94	94	0,
3	5	419	78	241	79	79	0,

Note: Comma represents decimal point.

Table 6

Site quality report for the soils of kolkhozes in the _____ rayon

Name of kholkhoz	Area, ha	Groups										Total no. of points	Area cov. by water	Average index value		Cor-rected local cond. C ₁	Aver. index val. with corrected C ₁	
		First			Second			Third						1	2		1	2
		Cherno-zems	dr-gray	gray	lt.-gray	Pod-zolic	Sod-meadow	wt.-log. sod-meadow	humic bog	peat bog								
Karl Marx	12500 Bi BiP	2000 100 200000	3000 90 270000	2500 70 175000	500 60 30000	100 30 30000	1900 60 414000	500 30 15000	400 10 4000	1500 10 15000	100							
etc.												826000		69	81	0,9	62	73
Total no. of hectares and pts. for the rayon		--	--	--	--	--	--	--	--	--	--	--	--	52	64	0,8	42	51

Note: 1 — as reduced to the total area; 2 — as reduced to the area occupied by group I and II soils.

Table 7

Description of the rayons of the Oblast' by categories of local conditions (for group I and II soils)

Rayons	Number of kolkhozes according to categories								Total no. of kol- khozes	Aver. index value	Cate- gory	
	II	III	IV	V	VI	VII	VIII	IX				
Subzone where gray forest soils predominate												
Kozhevnikovo	9	7	6	1	—	—	—	—	23	75	III	
Shagar	1	5	3	7	2	—	—	—	18	66	IV	
Krivosheinsk	—	—	3	5	4	—	—	—	12	53	V	
Tomsk	—	—	—	8	12	1	1	—	22	48	VI	
Tugan	—	—	4	6	2	8	—	—	20	46	VI	
Asinov	—	—	—	15	1	—	—	—	16	52	V	
Pyshkino-Troitsk	—	—	4	3	3	1	—	—	11	53	V	
Zyryansk	—	—	2	17	4	—	—	—	23	55	V	
For the subzone	10	12	22	62	28	10	1	—	145	55	V	
Subzone with sod-podzolic soils												
Vakchar	—	—	2	8	4	—	—	—	14	56	V	
Parbig	—	—	—	7	3	1	—	—	11	51	V	
Chain	—	—	—	—	13	7	1	—	21	41	VI	
Molchanovo	—	—	—	—	5	5	—	—	10	40	VII	
Kolpashevo	—	—	—	—	8	7	—	—	15	40	VII	
Parabel'	—	—	—	—	4	7	9	1	21	32	VIII	
Pudino	—	—	—	—	—	—	6	4	10	23	VIII	
Tegul'det	—	—	—	1	8	3	1	—	13	44	VI	
For the subzone	—	—	2	16	45	30	17	5	115	39	VII	
Subzone with podzolic and bog soils												
Verkhne-Ketsk	—	—	—	—	—	—	5	—	5	25	VIII	
Karagasok	—	—	—	—	—	—	11	1	12	24	VIII	
Vasyugansk	—	—	—	—	—	1	7	2	10	22	VIII	
Aleksandrovsk	—	—	—	—	—	—	2	2	4	22	VIII	
For the subzone	—	—	—	—	—	1	25	5	31	23	VIII	
For the Oblast'	10	12	24	78	73	41	43	10	291	45	VI	
In percent	3,4	4,1	8,3	27,0	25,3	14,1	14,4	3,4	100	—	—	

Note: Comma represents decimal point.

gray forest soils. Kolkhozes of the northern subzone, with predominantly podzolic and bog soils, have only categories VII, VIII, and IX.

More than half of the kolkhozes in the Oblast' belong to categories V and VI. As we can see from Table 7, conditions are favorable for agricultural production only in the subzone with predominantly gray forest soils. Evidently the knowledge of the differences between the rayons considerably facilitates agricultural management and makes it possible to actually differentiate the aid to each. From Table 7 it necessarily follows that the agricultural productivity in the rayons must correspond to the results of the qualitative evaluation of soils, which is confirmed in practice. Therefore regional management has a firm basis on which to plan and give the neces-

sary aid to the rayons and the rayons to kolkhozes. With a soil evaluation it is possible to establish more accurate production plans and norms for the procurement of agricultural products. Since the weighted average index value depends on soil fertility, low-category rayons and farms must be supplied with mineral fertilizers, and taught the techniques of preparing and placing organic fertilizers, and to establish their own system of agriculture. The method of the site quality of soils leaves room for increasing index values after proper soil rotation is introduced, fertilizers are used, and the thickness of the plowed layer is increased (Table 4). Since the index value depends on relief and outline, measures must be taken to overcome the difficulties associated with them, i. e., increase the areas by clearing forests, and reduce the unfavorable effect or relief by proper structures and the improvement of

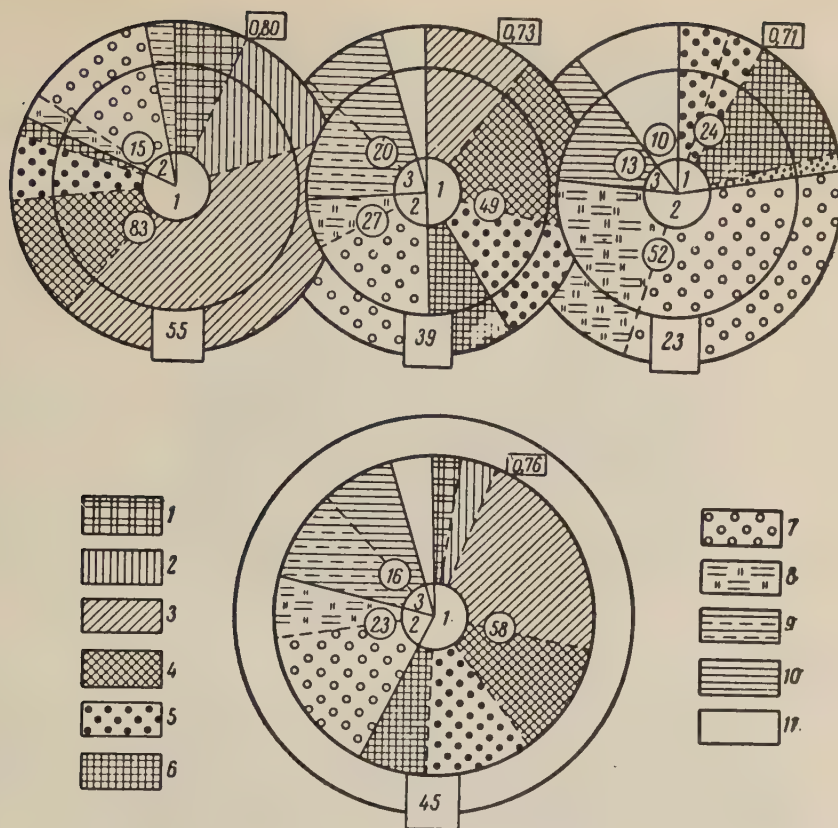


Fig. 1. - Structure and qualitative evaluation of soil by subzones. The numbers in the sectors in the inner circles represent productivity groups; circled numbers in the sectors represent percentages of soils of these groups. Numbers in the rectangles above the circles are the corrected coefficients for relief and contours; those below the circles represent points for group I and II soils for the subzones.

55 - index value for the subzone with gray forest soils; 39 - index value for the subzone with sod-podzolic soils; 23 - index value for the subzone with podzolic and bog soils; 45 - index value for the Oblast'. Soils: 1 - leached chernozem; 2 - dark-gray forest; 3 - gray forest; 4 - light-gray forest; 5 - sod-podzolic; 6 - podzolic; 7 - sod-meadow; 8 - water-logged sod-meadow; 9 - humus-peat; 10 - peat bog; 11 - water surface.

field roads.

Complicated relief and contours of fields require differential agricultural practices. Farms with small fields and complicated relief require suitable machines and implements, while farms with large fields and a smooth relief require other types of machines. Fast tractors are not suitable in the first case, while they are effective in the second.

Site quality, determined on the basis of the method described earlier, makes it possible to solve many practical problems.

If the land is used fully without expenditures on melioration, proper farm management can be established. If a farm has only soils of

group I, it must be used exclusively for field and forage crop rotation and eliminate the less productive natural pastures and hay fields. In addition to marketable crop production, such arable lands also produce more valuable forage crops than natural forage land. Such farms must "work" both on crop and livestock production. Cattle must be represented by good dairy cattle, while there must be less hog raising. Such a farming system is called a grain-livestock with emphasis on meat and milk.

Land with predominantly group II soils (there are such farms in the Tomsk Oblast') must be used for raising livestock for meat, selecting the proper cows for meat, since they eat hay in winter and forage from flood-plain meadows

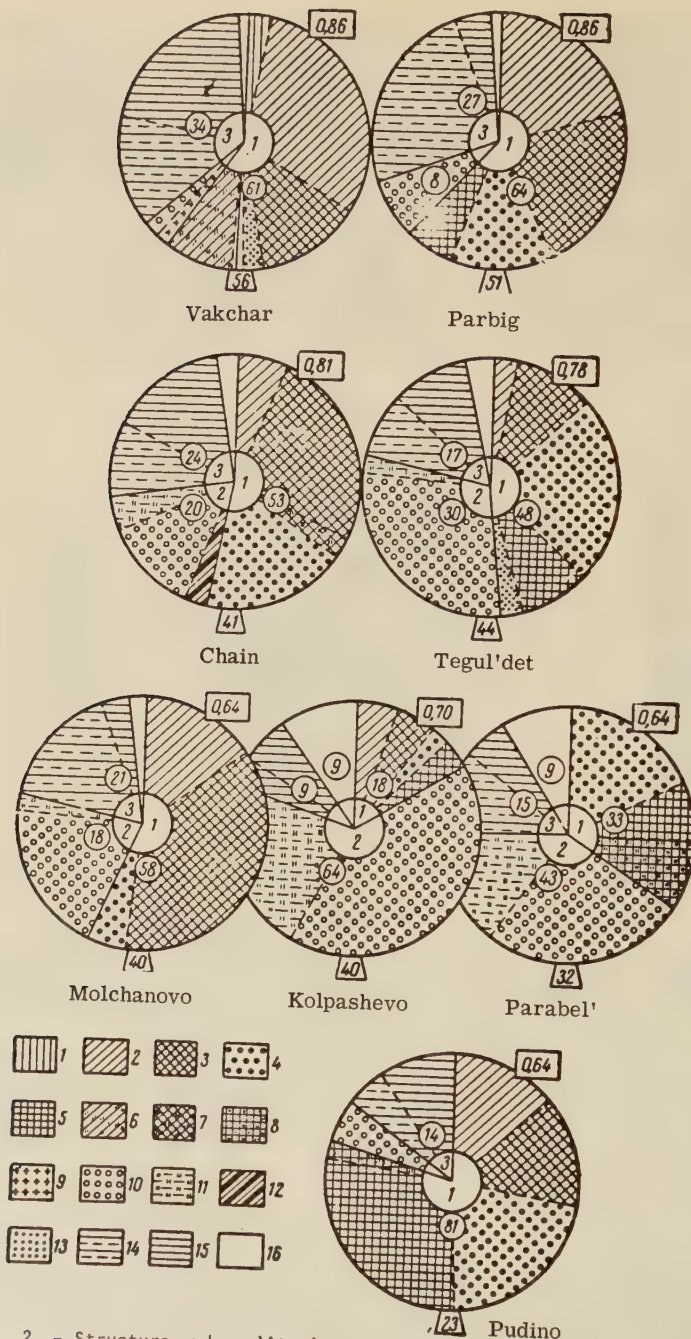


Fig. 2. - Structure and qualitative evaluation of soil for rayons in the subzone with sod-podzolic soils.

The numbers in the sectors of inner circles represent the productivity groups; those in sectors of large circles, the percentage of soils of these groups. Numbers in rectangles above the circles represent corrected coefficients for relief and contours; those below circles - index values of group I and II soils.

1 - dark-gray forest; 2 - gray forest; 3 - light-gray forest; 4 - sod-podzolic; 5 - podzolic; 6 - water-logged gray forest; 7 - water-logged light gray forest; 8 - water-logged podzolic; 9 - chernozem-meadow; 10 - sod-meadow; 11 - water-logged soils of river flood plains; 12 - complex soils on slopes; 13 - pine forest sands; 14 - humic-bog soils; 15 - peat-bog; 16 - water surface.

SITE EVALUATION

Table 8

Qualitative evaluation of local conditions and the cost of total agricultural production per 100 ha of land for 3 years (1955-1957)

Rayons of Tomsk Oblast'	Evaluation of local conditions		Cost of total production from 100 ha in rubles (as of 1961)	Major agricultural use
	Index	Category		
Subzone with gray forest soils				
Kozhevnikovo	75	III	36 400	Grain
Shagar	66	IV	26 400	"
Krivosheinsk	53	V	19 240	"
Tomsk	48	VI	27 800	Suburban
Tugan	46	VI	13 800	Grain
Asinov	52	V	28 000	Flax, grain
Pyshkino-Troitsk	53	V	18 400	Grain
Zyryansk	55	V	19 700	"
For the subzone	55	V	22 000	
Subzone with sod-podzolic soils				
Vakchar	56	V	23 200	Grain, flax
Parbig	51	V	11 900	Grain for livestock
Rain	41	VI	11 700	"
Molchanovo	40	VII	14 950	"
Kolpashevo	40	VII	11 740	"
Parabel'	32	VII	8 360	"
Tegul'det	44	VI	7 270	Livestock
Pudino	23	VIII	6 320	Grain for livestock
For the subzone	39	VII	12 450	
Subzone with podzolic and bog soils				
Kargasok	24	VIII	6 560	Livestock
Verkhne-Ketsk	25	VIII	4 180	"
Vasygan	22	VIII	3 960	"
Aleksandrovsk	22	VIII	5 920	"
For the subzone	23	VIII	5 350	
For the Oblast'	45	VI	16 630	

in summer.

In the presence of group I and II soils the farming system must be based on the ratio between the soil groups, taking into account their suitability for field crops or livestock.

It is impossible in a short article to discuss in more detail the interesting problem of the practical applications of the results of site quality studies in agricultural production. The results of site quality studies solve practical problems. A soil map helps in determining the actual areas where one or the other type of agriculture must be developed.

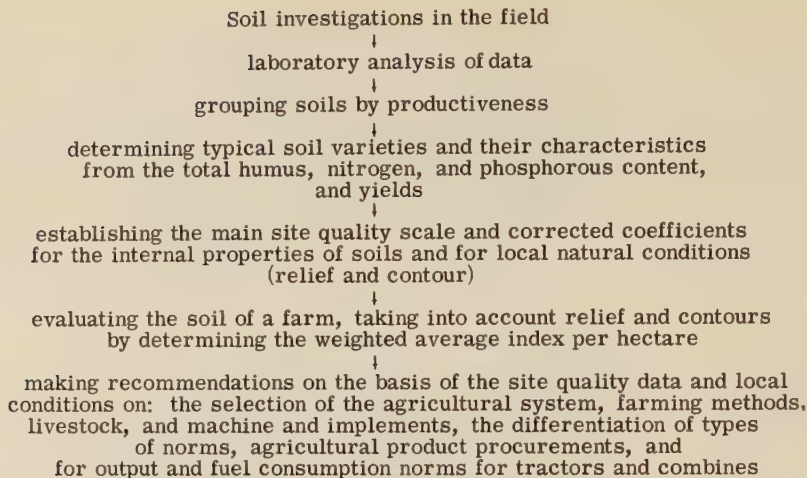
We compared the results of the qualitative evaluation of soil in rayons where the cost of total agricultural production is calculated per 100 hectares of kolkhoz land (Table 8)¹

---(see footnote 1 bottom next column)---

In comparing rayons with the same agricultural trends using Table 8 we can easily establish a relationship between the cost of total agricultural production and the category of local conditions.

The procedure of the qualitative evaluation of soil, starting from soil investigations in the field and ending with practical recommendations, can be described in the form of the following scheme:

¹The cost of agricultural production was calculated by economists from the Novosibirsk Institute of Agricultural Economy under the supervision of A. A. Garmash.



All these recommendations will be tentative and subject to discussion and approval at conferences and general meetings in kolkhozes and sovkhozes.

The method described needs improvement, including the elaboration of the initial index values, correction coefficient, more complete consideration of relief and contours, etc. However, in its present form, as used in the Tomsk Oblast', it is possible to evaluate comparatively local natural conditions and solve practically important problems of agricultural production.

The accuracy of the site quality of soil will depend on the quality of soil investigations in the field, of the laboratory analyses of the

samples, and on the quality of all office work. The proper identification of soil groups, the accuracy with which the contours are determined and maps compiled, and the proper execution of analyses are also important.

At the present time the soil scientists of the Regional Agricultural Administration are completing the summary reports on soil investigations at each farm by conducting site quality studies by the method described.

As experimental analyses showed, site quality studies of soils in test areas, land under various uses, and individual crop rotation fields are even more valuable.

METHODS

FRACTION OF READILY HYDROLYZABLE NITROGEN IN THICK CHERNOZEM, ITS COMPOSITION AND AGRICULTURAL-CHEMICAL IMPORTANCE

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Organic substances composing soil humus and containing nitrogen are generally stable compounds. Only an insignificant part of them are transformed to mobile state as a result of microbiological activity.

One of the principal forms of available soil nitrogen is the fraction of easily hydrolyzable nitrogen. A common method of determining it for the purpose of finding its degree of availability to plants is the method of Tyurin and Kononova (11). When a foregoing method is used (hydrolysis of 0.5 N H_2SO_4), the fraction of easily hydrolyzable nitrogen extracted from the soil consists of its mineral forms — nitrate and ammonium, and hydrolyzable organic forms — certain groups of amine and amide compounds. The latter may change to ammonium salts and nitrates under the influence of ammonifying the nitrifying bacteria under appropriate soil moisture and temperature conditions.

The content of easily hydrolyzable nitrogen, as the available part of the total soil nitrogen, is a rather characteristic value in various soil groups with variously stable humic substances. The content of easily hydrolyzable nitrogen in the plowed layer of podzolic soils and sierozems varies from 4% to 9% of total nitrogen, in gray forest soils it varies from 2%-3%, in dark-gray and chernozem soils, from 0.8-2.5%, and in chestnut and dark-chestnut soils, from 3.4%-6% (1, 2, 4, 5, 6, 7, 8, 9, 10, 11).

The percentage of easily hydrolyzable nitrogen with respect to the total amount often increases with depth along the soil profile (the studies were made to a depth of 50 cm), apparently as a result of the downward movement with water of the most mobile organic compounds (3, 5, 10).

The content of easily hydrolyzable nitrogen in the soil and the composition of its forms during the growing period are studied little from the dynamic point of view. At the same time this knowledge is necessary for determining the role of the easily hydrolyzable fraction of nitrogen in soil processes and in the nitrogen nutrition of plants. Such studies were made by us in 1958 on the thick chernozem of the Kursk Oblast'. The areas studied were virgin areas and a plowed field in the territory of the Central Chernozem State Reservation and the Kursk Agricultural Experiment Station. The

easily hydrolyzable nitrogen was determined in air-dry soil. An average sample from 5 borings was taken for analysis.¹

There are certain differences in the content of easily hydrolyzable nitrogen in the humus horizon of the soil under various land uses (Fig. 1). More easily hydrolyzable nitrogen accumulates in autumn in a non-mowed steppe and in the forest than where the grass is mowed annually, because of the decomposition of the litter. The amount of this nitrogen is even higher in a newly plowed virgin steppe (early fallow in crop rotation) as a result of the intense decomposition of the organic substance of sod and roots in the first years after plowing. The amount of easily hydrolyzable nitrogen decreases noticeably in old fallow soil (plowed virgin steppe under fallow since 1947) as compared to a non-mowed steppe, because of the absence of plant residues, but its content is still higher than in the soil of a mowed steppe, where available nitrogen is taken up by the grasses and is removed annually. The amount of easily hydrolyzable nitrogen decreases sharply in the plowed layer of old arable land (black fallow and winter wheat), but is similar to that of soil under other land uses in the lower-lying layers.

It follows from the foregoing that the content of the easily hydrolyzable fraction of nitrogen reflects to a certain degree the various states of virgin land: forest, mowed steppe, non-mowed steppe, and the time an area was used after the plowing of the virgin steppe — 6 years (early fallow), 11 years (old fallow), and old arable fields (black fallow, winter wheat).

The results of the dynamics of easily hydrolyzable nitrogen during the growing period are presented in Table 1.

No sharp changes in the amount of available nitrogen during the growing period were found in the virgin steppe. This is apparently attributable to the constant, gradual decomposition and mineralization at the soil surface of some part of plant residues. The content of easily hydrolyzable nitrogen decreased noticeably

¹The analyses were made by L. V. Kalyavkina.



Fig. 1. - Easily hydrolyzable nitrogen in the 0-40 cm layer of thick chernozem under various land uses, August, 1958.

1 - mowed steppe; 2 - mowed meadow; 3 - winter wheat; 4 - old fallow; 5 - black fallow; 6 - forest; 7 - non-mowed steppe; 8 - early fallow.

Table 1
Dynamics of hydrolyzable nitrogen in 1958, mg N/kg of soil

Depth, cm	Virgin steppe			Old fallow			Early fallow					Winter wheat	
	May 27	June 19	Aug. 22	May 27	July 16	Aug. 5	May 31	June 20	July 18	Aug. 14	Sept. 2	May 19	Aug. 22
0-5	99	66	83	69	66	85	62	69	63	91	63	63	46
5-10	83	91	91	63	58	60	58	72	77	77	77	47	44
10-20	66	60	66	58	63	44	63	52	66	58	66	54	44
20-40	65	51	55	43	52	47	—	—	—	—	—	—	—
40-60	51	45	—	39	33	52	—	—	—	—	—	—	—

Table 3
Content of mineralized and organic nitrogen in the composition of easily hydrolyzable nitrogen, %

Depth, cm	Nitrogen											
	Miner- alized	Organ- ic	Miner- alized	Organ- ic	Miner- alized	Organ- ic	Miner- alized	Organ- ic	Miner- alized	Organ- ic	Miner- alized	Organ- ic
	Old fallow						Steppe		Winter wheat			
	May 27		July 16		August 5		June 19		May 19		August 22	
0—5	80	20	89	11	100	0	50	50	24	76	54	46
5—10	54	46	59	41	65	35	27	73	—	—	—	—
10—20	60	40	65	35	73	27	38	62	33	67	41	59
20—40	84	16	73	27	77	23	30	70	52	48	41	59
40—60	100	0	100	0	70	30	25	75	40	60	—	—
	Early fallow										Black fallow	
	May 31		June 20		July 18		August 14		Sept. 3		July 22	
0—10	32	68	84	16	62	38	95	5	20	70	70	30
10—20	32	68	90	10	57	43	100	0	49	51	75	25
20—40	22	78	64	36	40	60	70	30	49	51	41	59

Table 2
Composition of the easily hydrolyzable fraction of nitrogen, mg/kg of soil

Depth, cm	Old fallow												Steppe												Winter wheat																																														
	May 27				July 16				August 5				June 19				May 19				August 22																																																		
	Mineralized ^a		Organ- icb	Tot.	Mineralized ^a		N-NO ₃	NH ₄	Tot.	Mineralized ^a		Organ- icb	Tot.	Mineralized ^a		N-NO ₃	NH ₄	Tot.	Mineralized ^a		Organ- icb	Tot.	Mineralized ^a		N-NO	NH ₄	Tot.	Organ- gan- icb																																											
	N-NO ₃	NH ₄	N-NO ₃		NH ₄	N-NO ₃	NH ₄	N-NO ₃		NH ₄	N-NO ₃	NH ₄		N-NO ₃	NH ₄	N-NO ₃	NH ₄		N-NO ₃	NH ₄	N-NO ₃		NH ₄	N-NO	NH ₄																																														
0—5	20	34	54	15	27	32	59	7	78	22	100		0,4	33	33	33	1	14	15	48	8	17	25	21																																															
5—10	17	17	34	29	17	17	34	24	28	11	39	21	0,4	25	25	66																																																							
10—20	21	14	35	23	28	13	41	22	20	12	32	12	0,8	22	23	37	2	13	15	31	2	16	18	26																																															
20—40	26	10	36	7	28	10	38	14	25	11	36	11	Not det.	15	15	36	13	15	28	26	Trace	18	18	26																																															
40—60	31	9	40	Trace	28	10	38	Trace	25	11	36	16	"	11	11	34	14	10	24	36	Not det.	18	18	—																																															
												Early fallow												Black fallow																																															
												July 18												August 14												Sept. 2												July 22																							
May 31												June 20												July 18												August 14												Sept. 2												July 22											
0—10	3	17	20	42	30	28	58	11	26	14	40	23	63	24	87	4	5	8	13	50	25	10	35	15																																															
10—20	5	14	19	39	54	11	65	7	30	14	44	33	57	24	81	Trace	30	8	38	39	23	10	33	11																																															
20—40	4	10	14	49	19	14	33	19	12	14	26	40	17	23	40	18	25	7	32	24	11	12	23	33																																															

in the soil under winter wheat from spring to autumn. The amount of easily hydrolyzable nitrogen increased insignificantly in the plowed layer of early fallow (oat stubble plowed under on May 20) in the summer-autumn period as compared to its amount in the spring, namely: from 60-70 mg of nitrogen per 1 kg of soil. In general the amount of easily hydrolyzable nitrogen is rather constant during the growing period.

The composition of the easily hydrolyzable fraction of nitrogen in thick chernozem varies with land use because of the different amounts of mineral and organic nitrogen compounds in it.

As we can see from the data in Tables 2 and 3, mineralized forms of nitrogen (nitrates and ammonia salts) are the main components of easily hydrolyzable nitrogen in fallow soil. During the period of maximum nitrification (June and August in 1958) hydrolyzable nitrogen in the plowed layer of the fallow consisted of 80%-100% and in the subplow layer of 70%-80% mineralized nitrogen, primarily nitrates. Organic nitrogen substances were found in considerable amounts only in spring at the beginning of the soil fallowing period and then accumulated in autumn in the area of early fallow. Consequently, during the time of soil fallowing considerable changes take place in the ratio between the mineral and organic parts of easily hydrolyzable nitrogen while its total content changes little. Under conditions of fallow soil cultivation the easily hydrolyzable fraction of nitrogen is represented primarily by its mineral forms, available to plants.

Under winter wheat and steppe vegetation the easily hydrolyzable fraction of nitrogen consists primarily of actually hydrolyzed organic compounds. Table 3 shows that they amount to 60%-72% in the layer from 0-20 cm and to 50%-70% in the layer from 20-40 cm. The accumulation of such forms of nitrogen in the soil under dense vegetation indicates that ammonification and nitrification are weakened as compared to fallow. Mineral nitrogen is represented here by ammonium compounds. Nitrates, being taken up by plants, do not accumulate in the soil. They are found in the surface layers only after vegetation is removed. For instance, determinations two weeks after the wheat was harvested (August 22, Table 2) showed that the amount of mineral nitrogen in easily hydrolyzable nitrogen increased, while the amount of its actually hydrolyzable organic compound decreased by more than half as compared to determinations made in the spring (21 mg against 48 mg of nitrogen per 1 kg of soil).

Conclusions

1. The amount of easily hydrolyzable fraction of nitrogen in thick chernozem is rather stable during the growing period.
2. The content of easily hydrolyzable nitrogen in thick chernozem under various land uses reflects the peculiarities of the dynamics of organic substances containing nitrogen.

3. The composition of the easily hydrolyzable fraction of nitrogen differs in fallow soil and under plants. Under the conditions of fallow cultivation this fraction is represented primarily by mineral forms of nitrogen, and under plants, by its organic compounds, which change into mineral forms only under certain conditions favorable to biochemical processes.

4. The availability to plants of available nitrogen cannot be characterized simply by the amount of the easily hydrolyzable fraction of nitrogen without considering the conditions of the ammonification and nitrification of this fraction.

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WATER CONSERVATION IN THE TRANS-VOLGA CHERNOZEMS DURING THE ENTIRE SNOWLESS PERIOD OF THE YEAR

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Many investigators in the field of soil science and agriculture have established that the physical properties of soils have a direct influence on the supply, movement, and consumption of soil moisture. There are many important papers on this problem (12, 13, 17, 18, 23, 25, 26, 28). The individual aspects of the moisture regime of soils in various natural zones have also been studied (1, 2, 4, 9, 10, 16, 20, 22, 29, 30). It must be noted, however, that the qualitative indices of the most important physical properties of soils under the conditions prevailing in the Trans-Volga region have not been fully determined yet. Such studies would make it possible to establish a better system for regulating the moisture regime of the soils. One of the objectives of our studies was to solve the problem of the structural-aggregate composition and structure of the plowed layer of Trans-Volga chernozems most favorable for increasing their fertility. First this problem had to be brought into agreement with the problem of soil moisture, a factor which sharply limits the development of plants in the Trans-Volga region. Practical methods had to be planned for creating and maintaining conditions ensuring the accumulation of moisture in the soil and its conservation from unproductive losses during the entire snowless period of the year.

As we know, under the conditions in the southeast cultivated plants often suffer not as much from the lack of precipitation as from the fact that a considerable part of it is lost on evaporation from the soil surface besides the plants. In certain regions (Saratov, Kuybyshev, for instance) the total moisture loss by evaporation from the soil is about 150-170 mm a year, or about 40% of the annual precipitation. Under the same conditions the loss by evaporation from the soil surface, excluding plants, is 130-140 mm during the growing period of spring wheat, or 30% of the total annual precipitation (7, 8).

The studies conducted in recent years give reason to believe that moisture evaporation from fallow soil and soil under cultivated plants is governed first of all by the aggregate composition and structure of that soil layer which is cultivated prior to and after planting. The moisture lost on evaporation from the soil surface is derived from that rising to the surface in capillary-liquid form, as well as in the vapor form (5, 11, 19).

Movement of moisture in the vapor form and its evaporation into the atmosphere are considerably greater when the upper part of the plowed layer consists of coarse blocky units. Evaporation is at a minimum in soil with fine granular structure. The elimination of moisture flow to the evaporation surface in the capillary-liquid state made it possible to determine the role of non-capillary pores¹ in the evaporation of moisture from the soil. Excessive non-capillary porosity and the strong aeration of the soil result in the blowing off and moisture rise from the lower-lying horizons. In this case evaporation has 2 maxima: the first at the boundary with the maximum non-capillary porosity (more than 40% of the total), and the second, at the boundary with the maximum capillary porosity (more than 70% of the total).

As a result of studies (5, 7, 11) the optimum aggregate composition and structure of chernozem soils have been established. A favorable diameter for predominating aggregates in the Trans-Volga region is 0.25 to 3-5 mm in diameter; the best ratio of conventional capillary porosity to non-capillary porosity varies from 1.5-2.0 (with a total porosity of 60% to 65%).

Under the best physical conditions of the plowed layer moisture evaporation from the soil decreases 1.5-2 times. The decrease in moisture evaporation is more noticeable under vegetation than in a fallow field.

The protective effect of vegetation is most pronounced when the upper part of the plowed layer is cloddy and coarsely granular and the non-capillary porosity of the soil is high (7).

Our studies from 1950-1960 made it possible to use earlier results for solving a number of agricultural practices for the dry-land Trans-Volga region. It has been established on the basis of special experimental crop

¹By conventional capillary pores we mean pores which fill with water when a soil column 10 cm high and placed 10 cm from the source of water is saturated. Non-capillary pores are determined by subtracting the capillary porosity from the total porosity.

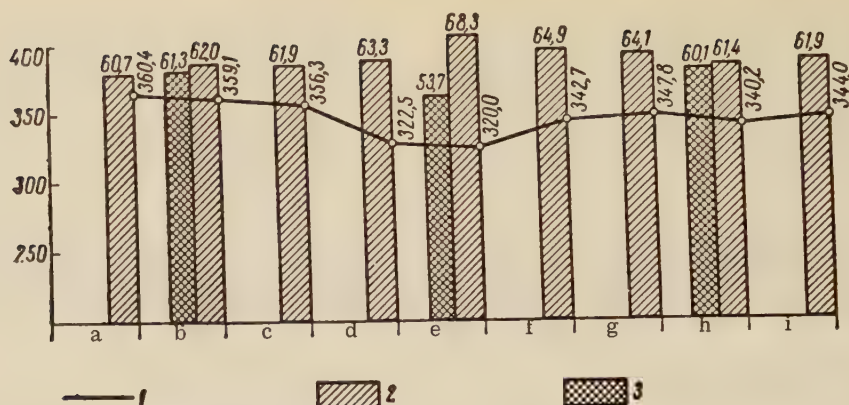


Fig. 1. - Dynamics of soil moisture and of the water-stable aggregates under crop rotation.

a - black fallow. Crop: b - winter; c - spring with a companion crop; d - 1-year old grasses; e - 2-year old grasses. Crop: f-g - spring; h - row crop; i - spring. 1 - soil moisture, mm; 2 - microstructure > 0.25 mm in diameter; 3 - microstructure 0.25-0.05 mm diameter.

rotations in the experimental field of the Kuybyshev Agricultural Institute that in spite of the large amount of macrostructural aggregates in the plowed layer of grass arable sequence as compared to fallow row crop sequence, the amount of moisture in the root zone in early spring was lower in the first case than in the second,² as shown in Figure 1.

This is attributable not only to the drying of the perennial grasses, but also to the greater amount of cloddy and coarsely granular aggregates (greater than 3 mm in diameter) in the plowed layer under grass-arable crops, which result in the increased moisture evaporation from the soil surface not only during the spring-summer, but also during the autumn-winter period after the fall late plowing. This is confirmed by the fact that the percentage of microstructural aggregates (0.25-0.05 mm in diameter) is higher under fallow row crops than under grass arable crops, as shown in Figure 1.

In those areas of the Trans-Volga region where perennial grasses give economically justifiable yields it is considered expedient to plant over the sod crops that require less soil moisture and utilize summer precipitation better than other crops, such as for instance millet, etc. It is recommended that the sod in such fields be prepared thoroughly after autumn plowing to lower the ridges and cloddiness of the fields and promote the

utilization of autumn precipitation and conserve it from losses in autumn and winter. Moisture evaporation from the soil in the southeast is associated with the convection and diffusion of vapor in the air of the soil and with the moisture flow in a capillary-liquid state. Therefore, it is necessary to loosen the upper part of the plowed horizon with a system of soil cultivation implements to prevent the moisture flow in the capillary liquid state and to reduce evaporation resulting from the convection and diffusion of water vapor (compacting and smoothing of the surface). Studies by Dolgov (11) showed convincingly the necessity of creating such a structure in the plowed layer which would considerably decrease moisture evaporation from the soil resulting from water vapor diffusion.

A favorable chernozem soil structure can be maintained not only by growing perennial legume-grass mixtures where possible, but primarily by plowing the subplow layer of chernozem soils to various depths in fallow row-crop rotation, especially in areas where the yield of perennial grasses is low.

The results in the experimental field of the Kuybyshev Agricultural Institute, presented in Table 1, show that when annual crops are grown 4 years in succession (1954-1957) the amount of water-stable aggregates decreases only in the plowed layer, primarily in its upper part. The amount of aggregates 0.25-5 mm in diameter even increases in the subplow layer which is not cultivated annually.

In relation to this it is very important agriculturally to establish a system of periodic plowing to various depths, reaching the aggregate part of the subplow layer, every 4 or 5 years (15). However, the dimensions of the aggregates alone do not always ensure such a structure of the plowed layer which is favorable in the Trans-Volga region. Therefore,

²The size of experimental crop rotation fields was 0.5 ha. Crop rotation was introduced in 1947. Soil moisture was determined gravimetrically in replicates. The water sieving was made by shaking the sieves (Baksheyev, TSKHA) and the soil samples were prepared by the Savinov method. This was repeated 3 times. Microaggregate analysis was made by the pipette method. Samples for analysis were taken from similar areas, selected for this purpose.

WATER CONSERVATION

Table 1

Influence of annual crops and perennial grasses on the structural properties of the soil^a

Crop sequence in 4 years	Soil layer, cm	Water-stable aggregates >0.25 mm in diam at the end of the experiment, %	Increase (+) or decrease (-) as compared to the initial content
Alfalfa and Agropyrum the 1st, 2d, and 3d yr. wheat	0-10	54,6	+ 4,1
	10-25	57,5	+ 7,0
	25-40	60,9	+ 10,4
Sudan grass, oats, oats, wheat	0-10	48,0	- 2,5
	10-25	51,7	+ 1,2
	25-40	59,8	+ 9,3
Fallow, winter rye, oats, wheat	0-10	46,2	- 4,3
	10-25	54,2	+ 3,7
	25-40	56,4	+ 5,9
Fallow for 4 years	0-10	41,9	- 8,6
	10-25	51,9	+ 1,4
	25-40	55,9	+ 5,4

^aThe mathematical analysis of the results showed that the changes in structural composition in the upper (0-10 cm) and lower (25-40 cm) soil layers are completely reliable; the observational accuracy ($t = \frac{M_1 - M_2}{md}$) under all treatments is greater than 3.

Note: Comma represents decimal point.

the ratio between large and small pores must be changed in the desired direction by using appropriate soil cultivation implements. For this purpose we conducted corresponding experiments with winter crops (rye and wheat) on black fallow and spring wheat and millet on fall-plowed soil at the experimental field from 1941-1957,3

Figure 2 shows the average data obtained as a result of a number of field experiments with the spring-summer tillage of black fallow. As we can see, the change in the medium inhabited by winter rye differs noticeably from one experimental treatment to another.

In those areas where the soil was rolled after being cultivated twice (first treatment) the ratio between capillary and non-capillary pores was favorable for the region studied (63.9 and 36.1).

As a result of the better structured plowed

layer under this treatment, there was more moisture in the soil at the seeding time of winter rye and the conditions were most favorable for providing plants with mineral nutrients.

Less favorable conditions for conserving soil moisture and accumulating plant nutrients were created by the second and third treatments without rolling, because of the more narrow ratio between capillary and non-capillary pores (51.3 and 48.7).

To conserve fully soil moisture accumulated during the autumn-winter period, to mobilize plant nutrients, and to control weeds effectively, spring-summer cultivation of black fallow must combine layer-by-layer and surface cultivation. The first two shallow plowings and cultivations, which must reach a greater depth (10-12 cm, 8-10 cm) than the subsequent cultivation (5-6 cm), must be followed by rolling. If this is done in the proper sequence, a favorable structured layer is achieved which prevents the movement of moisture in the form of vapor and in the capillary-liquid state from the lower-lying horizons, reduces unproductive evaporation from the soil surface, and ensures a better mobilization of plant nutrients.

A favorable ratio between water and air creates favorable conditions for the growth and development of winter crops. A good combination of agricultural practices — loosening and rolling — ensures the simultaneous germination of weeds and their maximum

³The field experiments with all the crops were replicated twice. The size of the experimental plots varied from 500-1000 m². The plots were elongated and divided into 9 sections. Mathematical analysis revealed that the results were very reliable.

The reliability of the investigations ($t = \frac{M_1 - M_2}{md}$) in all cases varied from 3.1-6.2 during soil cultivation of winter rye, from 7.7 during cultivation for spring wheat, and from 4.1-7.9 during cultivation for millet.

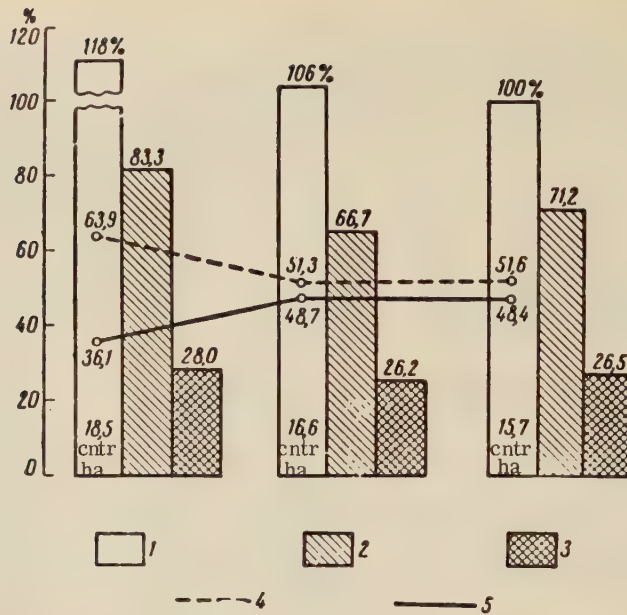


Fig. 2. - Influence of system of spring-summer cultivation of black fallow on structured plowed layer, soil moisture, and winter rye yields.
 a - shallow plowing and cultivating with a ring roller packer;
 b - same, but without packing; c - cultivating without a packer. 1 - winter rye yields, cntr/ha, %; 2 - NO_3 , mg/kg before seeding; 3 - moisture in 0-100 cm, %, before seeding. Porosity; 4 - capillary, % of total; 5 - non-capillary, % of total.

Table 2

Influence of the system of presowing cultivation on moisture evaporation from the soil and the yield of spring wheat

Indices	Soil cultivation			
	Cultivation with harrows		Cultivation with harrows + flat roller with loosening by seed harrows	
	Before the first cultivation	10 days after planting	Before cultivation	After planting
Soil moisture in the 0-10 cm layer, %	21,78	16,29	25,30	23,90
Soil moisture in the 10-20 layer cm, %	35,12	32,25	36,44	34,41
Moist. loss in 10 days in the 0-10 lay., %	—	5,49	—	1,40
Moist. loss in 10 days in the 10-20 cm ly. %	—	2,87	—	2,03
Total moisture losses by evaporation, mm	—	8,36	—	3,43
Spring wheat yield, cntr/ha	—	10,1	—	12,3

Note: Comma represents decimal point.

destruction during subsequent cultivations.

When early spring crops are planted, the period from the beginning of field work to the tillering of the crops is about 1 month. The soil surface, which is protected very little by vegetation during this period,

loses a considerable amount of moisture unproductively.

The object of presowing cultivation in this case is to impart to the cultivated soil layer such a physical structure that evaporation from the soil surface will be at a minimum.

As we can see from Table 2, the decrease in the amount of moisture in the soil in the plot cultivated without rolling reached 8.36 mm in 10 days. During the same period only 3.43 mm of winter were lost where cultivation was accompanied by rolling and loosening with seed harrows.

In spite of the relatively short period of time when the soil is bare of vegetation in spring, the unproductive moisture loss by evaporation from the soil surface is considerable. Moisture evaporation can be reduced by about half by changing the physical state of the cultivated layer with a system of presowing cultivation.

The data in Table 2 show that wheat yield on the rolled plot is higher by 2.2 ctnr/ha than in the non-rolled plot. Under the conditions of the Trans-Volga region the period between the early spring loosening of the autumn-plowed soil and the planting of late spring crops is often more than a month. The system of presowing cultivation must protect the soil surface from excessive losses of moisture by evaporation.

It has been established by special experiments that a system of presowing soil cultivation for late spring crops under arid conditions must include rolling after each relatively deep cultivation. A roller used in conjunction with seed-harrows creates a smooth soil surface, which evaporates less moisture, and at the same time stimulates the germination of weed seeds, especially after the first cultivation. In one of the experiments on a non-rolled plot the loss of water by evaporation during the period from the first cultivation (April 24) to the sowing of millet (May 26) reached 6.8% of soil weight and proved to be 2 times higher than in a plot which was rolled after the first cultivation and after seeding. The millet yield on the rolled plot was 2 ctnr/ha higher than on the non-rolled plot.

V. S. Minayev recently expressed the opinion that the presence of a compacted layer at a certain depth from the soil surface creates more favorable conditions for the condensation of atmospheric vapor in the soil (24).

In developing the theory of the directed utilization of vapor in the air layer near the ground, he assumed that the compacted layer in the plowed layer, being the coldest part of this horizon, must create favorable conditions for the condensation of vapor from the air layer near the ground. The compacted layer is cooler during the day than the upper layer of the soil and is warmer at night. Vapor will condense in the compacted layer during the daytime. At night part of the vapor derived from the lower layers of the plowed horizon will condense in the upper, colder layer of the soil after having passed the compacted layer, and drops of this water will moisten the compacted layer from above. Without over-emphasizing the practical importance of this, we must note that an increase of the condensation of atmospheric vapor in the soil will be desirable as one of the qualities created by rolling. Until recently investigations were directed toward determining the patterns, and quantitative and qualitative characteristics

of moisture evaporation from the soil, primarily during the spring-summer period. The problem of water losses by evaporation during the summer-autumn period before the establishment of a permanent snow cover has been hardly touched. Because of this, modern soil cultivation methods are still being established without considering the need of controlling moisture losses by the soil during this period.⁴

Our investigations show that the system of autumn soil plowing used at the present time does not always solve the problems of the accumulation and conservation of moisture in the soil and weed control. In most of the cases when autumn plowing is done with skim coulters, even when preceded by shallow plowing, fields in the southeast remain ridged-cloddy.

There is an opinion that a rigged-cloddy autumn-plowed field retains moisture better after the late summer and during the autumn-winter period. Observations show that this opinion is erroneous.

A field under pure fallow does not accumulate moisture in summer, but loses it. The accumulation of moisture takes place during the autumn-winter period. Therefore, such conditions must be created during the period of soil moisture accumulation which would promote its maximum absorption and conservation from unproductive losses.

One of the great agronomists, Izmail'skiy (4), pointed out that soil moisture depends as much on the nature and structure of the soil surface as on the amount of precipitation, and that with the same amount of precipitation one soil will accumulate moisture while another soil will lose it and dry out, depending on its state of cultivation.

P. A. Kostychev (21) pointed out that the fields must be smoothed in snow-free areas where the soil may dry out in winter in order to smooth its surface and create a friable surface layer on it which would keep it from drying, but let the rains through. We must create such conditions under which not only winter and summer precipitation, but also autumn precipitation are utilized to the fullest.

In recent years the sovkhoses and kolkhozes of the southeast have adopted the system of smoothing the surface of autumn-plowed fields in the fall to create in certain cases more favorable conditions for the accumulation and conservation of moisture in the soil than are created by a ridged and cloddy field. Such a system is used in the sovkhoses and kolkhozes of the Orenburg, Stalingrad, Kuybyshev, and other Oblast's of the southeast, covering an area of more than a million hectares. Observations showed that autumn-plowed fields, cultivated in the fall in the same manner as semi-fallow, or only harrowed, increase the

⁴We must consider the fact that part of the soil moisture can be lost to the air layer near the ground during the winter months (3).

quality of presowing soil cultivation in the spring, allow earlier sowing, and reduce the cost of the harvest. Fields plowed in early autumn and not cultivated in the fall often become covered with weeds, and are subject to the windfall of grain crops, which leads not only to the drying of the soil and a decrease in the amount of nutrients, but to the accumulation of pest larvae and agricultural crop diseases. The system of the fall maintenance of autumn-plowed fields reduces the negative effects of a drought at the beginning of the summer period and ensures an increase in crop yield (Table 3).

It has been established in the fields of the "Samarskiy" sovkhos, Kuybyshev Oblast', that 150-200 metric tons/ha more moisture accumulates from August to October in the upper 0.5 mm of the soil in autumn-plowed smooth fields than in an autumn-plowed ridged field. It has also been established that weeds germinate more evenly and in larger amounts in areas of an autumn-plowed field which had been rolled or harrowed in the fall.

According to the data of the Orenburg Scientific-Research Institute of Milk and Beef

Cattle Breeding, 2.6-6.0 weeds per 1 m² were found in a ridged field in the Kuybyshev kolkhoz, Chkalov rayon, which was plowed to various depths in the autumn, while in a smooth field there were 11.6-51.4 weeds per 1 m².

There is an opinion that in the southeast a ridged surface promotes moisture accumulation by its better retention of snow. This is not true. Observations in the winter of 1959-1960 (which had little snow) in the fields of the educational farm of the Kuybyshev Agricultural Institute, showed that during the second part of January snow depth averaged 16.8 cm in a ridged autumn-plowed field, while in a smooth field it was 19.2 cm. By the end of March the ridged field had a snow cover 18.1 cm thick, while the snow in the leveled field was 17.5 cm thick. As we can see there was no difference between snow cover thickness in the autumn-plowed ridged and smooth fields throughout the entire winter period.

Smoothing of a field cannot be limited only to harrowing after plowing. The best effect is obtained when the system of soil cultivation ensures not only the prevention of moisture

Table 3

Smoothing of autumn-plowed fields in the fall and the yield of agricultural crops in the southeast

Farm location	Year	Crop	Cr.yd.in aut. -pl.fld.cha		
			Smooth fields	Ridged fields	Increment
Kuybyshev Oblast'					
Chapayev rayon, Lenin sovkhos	1955	Spring wheat	11,0	9,0	2,0
Bol'she-Glushitsk rayon, Frunze sovkhos	1959	Same	10,5	8,0	2,5
Shentalin rayon, "Kanash" sovkhos	1958	Ensilage corn	200,0	180,0	20,0
Orenburg Oblast'					
Buzuluk rayon, Furmanov kolkhoz	1952	Spring wheat	8,3	6,4	1,9
Same, "Pervaya pyatiletka" kolkhoz	1958	"	20,6	17,6	3,0
Scientific-Research Institute of Milk and Beef Cattle Breeding	"	"	9,9	8,9	1,0
Penza Oblast'					
Pachelma rayon, "Titovskhiy" sovkhos	1959	Spring wheat	7,9	6,8	1,0
Kamensk rayon, "Serp i molot" sovkhos	1959	Corn on cobs	—	—	7,0
Ul'yanyov Oblast'					
Trengul Machine Traction Station, Kalinin kolkhoz	1956	Spring wheat	14,5	11,6	2,9
Trengul Machine Traction Station, Kalinin kolkhoz	1956	Millet	15,0	10,0	5,0
Stalingrad Oblast'					
Kamyshin experiment station	1959	Millet	12,6	7,4	5,2

Note: Comma represents decimal point.

evaporation, but reduces weeds. Therefore, after an autumn-plowed field is harrowed it must be cultivated once or twice before cold temperatures set in.

The favorable effect of smoothing on the conditions for the growth and development of crops is noted not only in autumn, but also during the spring-summer period. Observations made by the personnel of the Kuybyshev Agricultural Institute in the "Samarskiy" sovkhos (where part of an autumn-plowed field was smoothed in the autumn of 1958) gave the following results: the number of clods larger than 5 cm in diameter was 17/m² in the leveled areas before the autumn planting of wheat, while in non-smoothed areas it was 43/m².

In 1960 it was found in the same sovkhos that during the period of the presowing soil cultivation in spring the amount of structural aggregates of the most favorable diameter (0.25-3.0 mm) was 60% in areas which had been smoothed in autumn, which is 10%-15% more than in the areas which were not smoothed.

Spring wheat germination in the smoothed field was 91.2% and in the non-smoothed field 80.9%. The spring wheat yield in autumn-plowed fields smoothed in the fall was from 1-3 cнtr higher and that of millet 2-3 cнtr higher than in the autumn-plowed ridged field.

Because weeds germinate more rapidly and evenly in a field smoothed in autumn, they are destroyed in larger amounts during subsequent soil cultivation. Thus, as of June 25 there were 36 weeds per 1 m² among the millet planted in a smoothed field in the same sovkhos, while in the ridged field there were 79 weeds per 1 m².

Considering the positive effect of such a method on the yield of agricultural crops, 4000 ha of autumn-plowed fields were smoothed and planted in the "Samarskiy" sovkhos in 1960. This produced an additional yield of grain crops amounting to 35,000 poods.

The system of smoothing autumn-plowed fields in the fall must find wide application in the southeast, especially in the kolkhozes and sovkhos of its steppe part. In these most dry regions, where the frost-free period is longer, where a permanent snow cover forms only at the end of November-early December, and the snow cover is shallow, a ridged and cloddy soil surface sharply reduces the amount of moisture in the soil.

The climate is dry in all the regions of the southeast, and therefore we must take into consideration the relief of lands under various uses in each farm, and rationally combine the system of smoothing autumn-plowed fields in the fall with erosion control measures. Because of the variability of meteorological and soil factors from year to year and from growing period to growing period, the blind use of given methods in the system of soil tillage must be avoided.

Conclusions

1. The unproductive evaporation of moisture from the chernozem soils of the Trans-Volga region must be controlled by creating a composition with predominantly small granular aggregates (0.25-3.5 cm in diameter) by means of a proper system of crop rotations and plowing to various depth.

- A structure of the plowed layer must be maintained in which capillary pores comprise 60%-70% of total porosity by cultivation after plowing the soil.

2. The necessary plowed layer structure can be maintained by using appropriate systems of autumn cultivation of shallow plowing the spring-summer cultivation of black fallow for winter crops, and the pre-and after-sowing cultivation of autumn-plowed fields for early and late spring crops, where in addition to plows, surface-plows, cultivators, and harrows are used which smooth and compact the soil, such as ring and flat rollers, as well as special plowing units.

3. Considering that in the southeast moisture is lost unproductively by the soil not only during the spring-summer, but also in the summer-autumn periods, autumn-plowed fields must be maintained during cultivation in a smooth and fine granular state, which inhibits the aeration of the plowed layer. This is achieved by smoothing autumn-plowed fields in the fall.

4. The change in the structural-aggregate composition and structure of the soil achieved by tillage implements leads to the accumulation and conservation of soil moisture — a most important element of soil productivity in the Trans-Volga region.

A favorable ratio between water and air ensures in addition an increase in the amount of available nutrients, creates good conditions for plant growth and development, and increases the yield of grain crops (winter rye, spring wheat, millet, etc.) by an average of up to 2-3 cнtr/ha, or 15%-18%.

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INFLUENCE OF CHLOR-ORGANIC COMPOUNDS ON SOIL FERTILITY AND AGRICULTURAL CROP YIELDS

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In recent years hexachlorane, heptachlor, and other preparations from the synthesis of chlor-organic compounds have come into wide use in agricultural practice and proved to be effective against agricultural pests, including soil pests (click beetles, beet weevil larvae, turnip moth grubs, cockchafer grubs).

In working for a number of years on the application of hexachlorane and heptachlor in the control of soil-inhabiting pests, we found that their positive effect when added to the soil is not limited to the destruction of pests. A number of our experiments on soils slightly infested by pests showed that the use of these compounds increases the yield of agricultural plants.

We studied the effect of the addition of hexachlorane and heptachlor to the soil on various agricultural crops (sugar beets, winter rye, winter and spring wheat, barley, oats, and potatoes) on various soils. The experiments were made in kolkhozes and sovkhoses of the Leningrad Oblast' on the podzolic sandy loams of the Kirishi rayon, the clay loam and calcareous soils of the Kingisepp and Vsevolzhskiy rayons, as well as in farms of the Cherkassk Oblast', Ukrainian SSR on leached chernozems and gray forest soils of the Kamensk and Semlyansk rayons.

The compounds were added to the soil during presowing cultivation. The size of the plots varied from 200 m² to 0.5 ha. The experiments were replicated 2-3 times. The soil was treated with hexachlorane and heptachlor in the Leningrad Oblast' in order to control click beetles and in the chernozem zone to control beet weevil larvae. The influence of hexachlorane on the agricultural crop yield is illustrated by the data in Tables 1 and 2.

As we can see from Table 1 the addition of the amounts of hexachlorane studies to the soil increases the yield of all the foregoing plants (sugar beets, barley, and winter wheat and rye). The favorable effect of hexachlorane on crop yield is shown not only in the year when it is added, but in the following years. As the crop yield increases so does its quality.

A similar effect on the yield of sugar beets

and potatoes is obtained from the addition of heptachlor to the soil, as we can see it from the data in Table 2. The crop yield increases even more when heptachlor is added to the soil together with mineral fertilizers.

We studied the stimulating effect of chlor-organic compounds on sugar beets in relation to moisture conditions and mineral nutrition in pot experiments. These experiments were made in the greenhouse of the Maslov Agricultural Technical School (Kiev Oblast'). The experimental setup was the following.

The first series under moisture deficiency conditions included the following treatments: 1 - control, 2 - prior to sowing seeds were dusted with 12% hexachlorane at a rate of 10 g per 100 g of seed (the presowing treatment of seeds with organic chlorine preparations is one way of adding insecticides to the soil); 3 - 0.15 g of 12% hexachlorane dust per 1 kg of air-dry soil were added to the soil before sowing sugar beets.

The second series was made under optimum moisture conditions. The treatments were the same.

The third series was made under optimum moisture conditions against a background of NPK (0.22 g; N, 0.21 g P₂O₅, and 0.24 g of K₂O per 1 kg of air-dry soil). The treatments were the same.

Each pot was filled with 10 kg of clay loam chernozem soil. Moisture was maintained at 30% in the first series of experiments and at 60% of total moisture capacity in the second and third series. The experiments were replicated 5 times.

As indicators of the growth of the plants we selected: a) area of leaf surface; b) dry weight of plants; and c) root and top yields of sugar beets.

As we can see from Figure 1, the area of leaf surface decreased sharply as compared to the control when hexachlorane was used to treat the seeds or added to the soil under moisture deficiency conditions. The leaf surface area increased noticeably under treatment with hexachlorane at optimum moisture conditions. An even greater increase was

Table 1

Influence of hexachlorane on the magnitude and quality of the yield of agricultural crops (Cherkassk Oblast', leached chernozem soil)^a

Rate of application of industrial hexachlorane, kg/ha	Sugar beets the year hexachlorane was added		Barley a year after the addition of hexachlorane		Oats the year hexachlorane was added		Winter wheat, hexachlorane was added in the aut. before sowing.	
	cntr/ha	Sugar content, %	cntr/ha	Absolute weight of grain, g	cntr/ha	Absolute weight of grain, g	cntr/ha	Absolute weight of grain, g
Control	153,8	18,5	19,8	34,32	15,60	29,72	28,0	36,05
5	159,0	18,9	—	—	15,90	30,67	29,8	36,85
10	168,0	18,9	23,0	35,55	18,56	30,90	30,6	37,41
20	167,8	19,5	22,7	35,87	22,40	30,38	32,1	38,62
30	170,8	19,1	23,0	35,37	—	—	—	—

^amD (experimental errors) is $\pm 3\%$ for sugar beets, $\pm 4\%$ for barley, $\pm 3.7\%$ for oats, and $\pm 5.1\%$ for winter wheat.

Note: Comma represents decimal point.

Table 2

Influence of heptachlor on the amount and quality of agricultural crops (amount of industrial heptachlor, 5 kg/ha^a).

Treatment	Sugar beets, leached clay loam chernozem, Cherkassk Oblast'		Potatoes, clay loam podzolic soil, Leningrad Oblast'	
	cntr/ha	Sugar content, %	cntr/ha	Sugar content, %
Control	185,1	16,8	152,8	18,2
Heptachlor	214,7	16,6	174,5	18,5
NPK	227,8	16,6	217,6	18,0
Heptachlor agnst. a bkgr. of NPK	265,5	17,1	237,6	13,6

^amD (experimental errors) is $\pm 2.9\%$ for sugar beets and $\pm 3.8\%$ for potatoes.

The fertilizers were added at rates of: 50 kg/ha of N in the form of ammonium nitrate; 60 kg/ha of P_2O_5 in the form of superphosphate; and 60 kg/ha of K_2O in the form of 40% potassium salt.

Note: Comma represents decimal point.

obtained from hexachlorane in the third series of experiments (optimum moisture against a background of NPK). A similar picture was observed as far as the dry weight 1 month after the appearance of shoots was concerned (Fig. 2).

Data on the influence of hexachlorane on plant yield depending on moisture and nutrition conditions are presented in Table 3.

As we can see from Table 3, the yield of sugar beets decreased under treatment with hexachlorane at moisture deficiency conditions and increased noticeably at optimum moisture conditions. An even greater yield increment was obtained from hexachlorane against a background of NPK.

The literature (2, 4, 13) mentions that the use of stimulants give the greatest positive effect when all the proper agricultural practices are observed. Grigor'yeva (4) believes that the sharp decrease in yield under unfavorable conditions is attributable to the fact that the moisture and mineral nutrition requirements of plants are not satisfied because of the intensification of exchange processes under the action of hexachlorane.

The foregoing experimental material also confirms that the reactions of the plants to the action of hexachlorane strongly depend on their moisture and nutrition conditions. Chlor-organic compounds have a stimulating effect only when the plants are provided with all that is necessary for their normal development. If the water

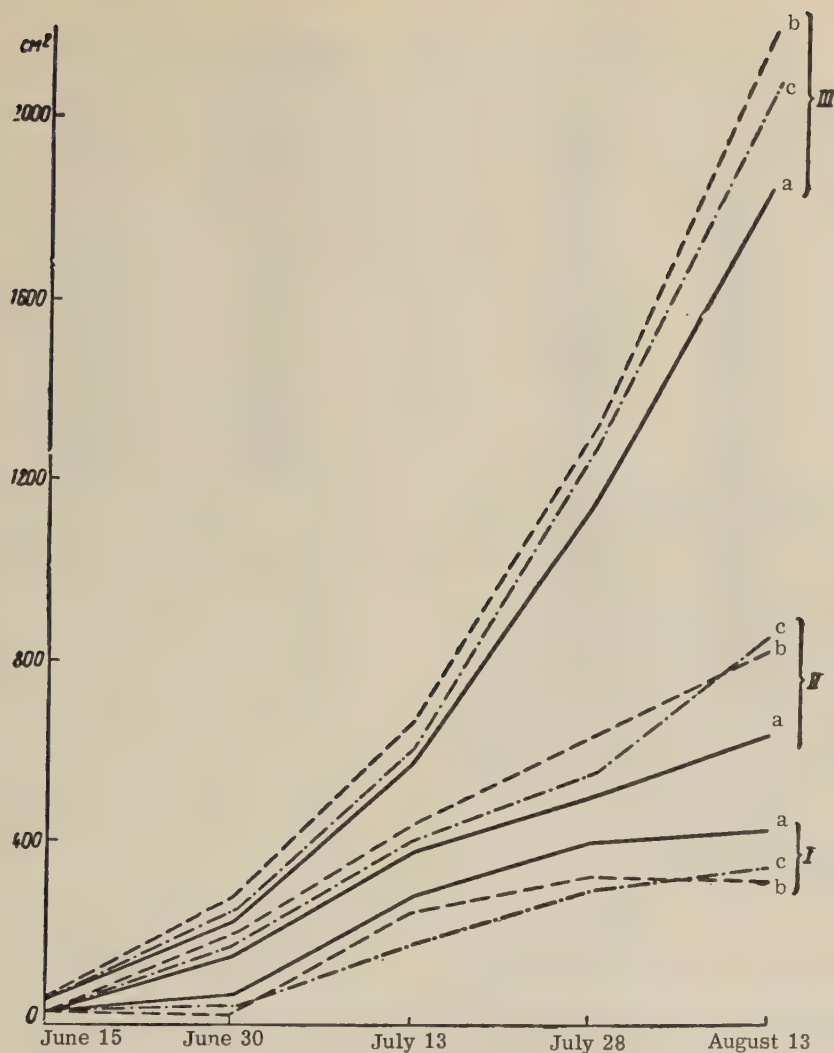


Fig. 1. - Change in the size of the leaf surface of sugar beet plants depending on conditions under which hexachlorancyclohexane was added. Moisture: I - deficient; II - optimum; III - same, against a background of NPK. a - control; b - seeds treated with hexachlorancyclohexane; c - hexachlorancyclohexane was added to the soil.

and nutrition regimes of the soil degenerate, the effect of hexachlorane on crop yield becomes negative.

The effect of hexachlorane of crop yield also depends on the soil texture. This is confirmed by an experiment conducted by us in the following setup.

The first series was made on fine clay loam chernozem under the following treatments: 1 - control; 2 - the seeds were dusted before sowing with 12% hexachlorane at a rate of 10 g per 100 g of seeds; 3 - 0.15 g of 12% hexachlorane per 1 kg of air-dry soil were added to the soil before sowing.

The second series was made on sandy chernozem. The treatments were the same. Each pot was filled with 12 kg of soil. The experiments were replicated 5 times. The texture and physicochemical properties of the soils in both series are given in Table 4.

The data in Table 4 show that the soils used in the experiment differ sharply in particle-size composition and in their physicochemical properties. As indicators of the plant growth we selected: a) number of shoots, b) dry weight of plants; and c) root and top yield of sugar beets.

As we can see from Figure 3, treatment of

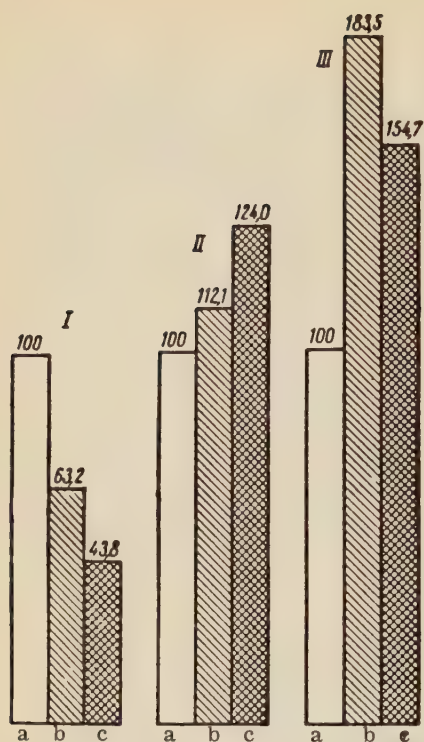


Fig. 2. - Change in the dry weight of sugar beets (% of control) depending on the conditions under which hexachlorocyclohexane was added (for the designations see Fig. 1).

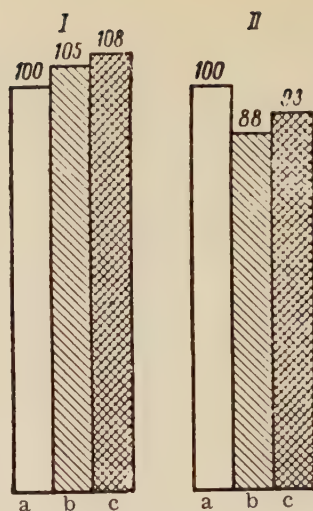


Fig. 3. - Influence of hexachlorocyclohexane on the germination of sugar beets (% of control) in relation to soil texture. Chernozem: I - fine clay loam; II - sandy. a - control; b - seeds were treated with hexachlorocyclohexane was added to the soil.

Table 3
Root and top yields of sugar beets under various experimental treatments^a

Treatment	Weight of one plant					
	Root			Top		
	g	Difference	% of control	g	Difference	% of control
First series - moisture deficiency						
Control	52,2	—	100	54,5	—	100
Seeds treated with hexachlorane	40,0	-12,2	76,6	36,5	-18,0	67,0
Hexachlorane added to the soil	31,1	-21,1	59,6	39,7	-14,8	72,8
Second series - optimum moisture						
Control	81,1	—	100	86,7	—	100
Seeds treated with hexachlorane	87,9	+ 6,8	108,4	102,6	+15,9	118,3
Hexachlorane added to the soil	94,0	+12,9	115,9	107,4	+20,7	123,9
Third series - optimum moisture against a background of NPK						
NPK Control	253,2	—	100	333,7	—	100
NPK + treated seeds	278,8	+25,6	110,1	416,6	+82,9	124,8
NPK + hexachlorane added to the soil	290,9	+37,7	114,9	368,4	+34,7	110,4

^amD (experimental errors) is $\pm 6.8\%$ for roots and $\pm 3.2\%$ for shoot.

Note: Comma represents decimal point.

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Table 4
Particle-size composition (%) and physicochemical properties of soils

Soil	Particle diameter, mm				pH of salt extract	Humus, % (according to the Tyurin method)	Adsorption cap. mg/100 g of soil (according to the Bobko-Askani method)
	>0,25	0,25—0,05	0,05—0,01	<0,01			
First series — fine clay loam chernozem	0,26	3,0	45,2	51,54	6,3	3,9	33,7
Second series — sandy chernozem	22,33	42,83	25,21	9,58	5,8	2,6	11,3

Note: Comma represents decimal point.

the seeds with hexachlorane and its addition to the soil produced less germination on sandy chernozem than in the control. The same amounts of hexachlorane in fine clay loam chernozem produced a noticeable increase in seed germination. Thus, one and the same amount of hexachlorane affects the germination of sugar beets differently, depending on soil conditions. A similar picture was observed with the dry weight a month after the appearance of the shoots.

As we can see from Table 5, the yield of sugar beets decreased under the effect of hexachlorane on sandy soil and increased on fine clay loam soil. Evidently the effect of hexachlorane on plants depends strongly on soil texture, which determines the concentration of poison acting on the plants.

We have mentioned the role of the soil as a regulator of the amount of hexachlorane as early as in 1948 (12). At that time we had established that in order to obtain the same

toxic effect on click beetle smaller amounts of hexachlorane are needed on poor sandy soils with a small adsorption capacity than on fine-textured soils with a high adsorption capacity.

As we know, there are contradictory opinions on the treatment of sugar beet seeds with hexachlorane, which is one of the means of adding the insecticide to the soil. Some believe that the treatment of seeds with hexachlorane has a positive effect on plants (6, 8). According to other investigators, the treatment of sugar beet seeds with the same amounts of hexachlorane causes the dying off of the shoots and a decrease in yield (5, 9).

The foregoing data explain the contradictory opinions on this problem. They are due to the fact that a number of investigators ignore and underestimate soil conditions under which the compounds are used.

We may conclude on the basis of our

Table 5
Root and top yields under various experimental treatments^a

Treatments	Weight of one plant					
	Root			Top		
	g	Difference	% of control	g	Difference	% of control
First series — fine clay loam soil						
Control	294,2	—	100	287,5	—	100
Seeds treated with hexachlorane	366,4	+72,2	124,5	349,8	+62,3	121,7
Second series — sandy soil	344,4	+50,2	120,2	332,6	+45,1	115,7
Second series — sandy soil						
Control	240,3	—	100	259,3	—	100
Seeds treated with hexachlorane	219,5	—20,8	87,3	229,7	— 28,6	88,6
Second series — sandy soil	149,0	—91,3	60,8	147,2	—112,1	56,8

^amD (experimental errors) is $\pm 4.9\%$ for the roots and $\pm 2.8\%$ for the tops.

Note: Comma represents decimal point.

Table 6

Effect of hexachlorane on the yield and sugar content of beets^a

Kolkhoz	Soil	Experimental treatment	Yield, ctnr/ha	Sugar content, %
"Druzhba"	Clay loam gray forest soil	Control (NPK)	275,8	15,9
Stalin	Coarse clay loam leached chernozem	Hexachlorane added to the soil against a background of NPK	332,0	16,3
		Control (NPK)	302,0	15,5
		Hexachlorane added to the soil against a background of NPK	368,7	16,0

^amD (experimental error) is $\pm 5.3\%$ in the experiment at the "Druzhba" kolkhoz and $\pm 6.8\%$ at the Stalin kolkhoz.

Note: Comma represents decimal point.

Table 7

Effect of hexachlorane in the year of its addition on the yield and sugar content of sugar beets (amount of industrial hexachlorane, 20 kg/ha)

Kolkhoz	Soil	Experimental treatment	Yield of sugar beets by years, ctnr/ha		Sugar content by years, %	
			1951	1952	1951	1952
Stalin	Leached medium clay loam chernozem	Control	245,5	243,8	19,9	15,3
		Exper.	289,8	315,2	19,9	18,7
Zhdanov	Degraded coarse clay loam chernozem	Control	191,0	—	19,7	—
		Exper.	225,4	—	19,8	—
Lenin	Gray forest medium clay loam	Control	180,2	160,1	18,7	14,7
		Exper.	249,3	193,0	18,8	15,3
"Zavadovka"	Light-gray podzolized clay loam	Control	174,3	237,8	18,5	14,0
		Exper.	204,6	295,1	18,8	15,6

Note: Comma represents decimal point.

investigations that the use of hexachlorane even in the same soil-climatic zone directly depends on soil conditions and in particular on texture, which determines many physical (porosity, cohesiveness, moisture, aeration, heat capacity) and physicochemical (adsorption capacity) properties of the soil.

We also observed an increase in yield and

the sugar content of beets under the effect of hexachlorane in field experiments conducted in 1958 in the "Druzhba" kolkhoz on clay loam gray forest soil, and in the Stalin kolkhoz on coarse clay loam leached chernozem in the Smelyanskiy rayon, Cherkassk Oblast', Ukrainian SSR. Winter wheat was planted on fallow in these fields and then sugar beets. The soil was fertilized for sugar beets in the

Table 8

Dynamics of the weight of the sugar beet roots in the kolkhozes of the Smelyanskiy rayon and neighboring rayons

Rayon	Treatment	Root weight, g									
		1957					1958				
		I.VII	20.VII	10.VIII	1.IX	20.IX	1.VII	20.VII	10.VIII	1.IX	20.IX
Smelyanskiy	All the kolkhozes added hexachlorane to the soil	47	106	187	219	251	38	99	194	278	343
Kamensk	Hexachlorane was not added to the soil	36	122	111	164	205	37	78	182	245	299
Gorodishchenskiy	Same	25	86	137	202	227	31	75	170	260	312

spring with 40 kg/ha of N in the form of ammonium nitrate, 40 kg/ha of K_2O in the form of 40% potassium salt, and 50 kg/ha of P_2O_5 in the form of superphosphate. Hexachlorane was added at a rate of 50 kg/ha in the form of 25% dust in ground phosphorite against the background of NPK. Data on the effect of hexachlorane on the yield and sugar content of the beets are presented in Table 6.

Judging by the data in Table 6, the beet yield in the "Druzhba" kolkhoz increased by 56.2 ctnr/ha and its sugar content increased by 0.4% under the effect of hexachlorane, while in the Stalin kolkhoz the increases were 66.7 ctnr/ha and 0.5%, respectively, as compared to the yield obtained with the addition of mineral fertilizers only.

The increase in the yield and sugar content of sugar beet under the effect of the addition of hexachlorane to the soil depends also on weather conditions. This was confirmed by the data obtained in field experiments in the kolkhozes of the Kamensk rayon, Cherkassk Oblast' (Table 7).

According to the data of the Mikhaylovsk base station of the All-union Scientific-Research Institute of Plant Conservation, the amount of precipitation during the growing period (April-October) of 1951 was 202.7 mm and that of 1952, 311.5 mm, i.e., the amount of precipitation during the growing period of 1952 was 1.5 times higher than during the same period in 1951.

The foregoing results of pot and field experiments fully agree with those obtained during production experiments in 1957-1958 in the Smelyanskiy rayon, Cherkassk Oblast', Ukrainian SSR.

In 1957, the production experiment with hexachlorane was made in all the kolkhozes of the Smelyansk Machine and Tractor Station, Cherkassk Oblast' which grow beets, covering an area of 2246 ha, and in 1958, in all the kolkhozes of the Smelyanskiy rayon in an area of 5300 ha.¹

The 25% hexachlorane in ground phosphorite was added to the soil by means of TR-1 fertilizer spreaders, KRS-8.1 cultivator-plant feeders, and 2SK-16 seeders at a rate of 50 kg/ha. Before being loaded onto the seeder the compound was mixed with mineral fertilizers and then spread. The 2-year experiment with the addition of hexachlorane to the soil showed that the foregoing machines fully mechanized the addition of the compound during presowing soil cultivation.

The addition of the mixture of hexachlorane and mineral fertilizers to the soil improved the development of beets. This is evidenced by the data from the observation points of sugar factories, which determined the average weight of the beets every 10 days (Table 8).

As we can see from Table 8, the average weight of sugar beet roots was higher during the entire growing period in the kolkhozes of the Smelyanskiy rayon than in neighboring kolkhozes where hexachlorane was not added to the soil. Hexachlorane had a similar effect on the top weight and on the sugar content of the beets, which, according to the data of the observation points of sugar factories, was higher in kolkhozes in the area of the Smelyanskiy Sugar Factory than in the kolkhozes of neighboring factories.

Thus, pot, field, and production experiments conducted in rayons and Oblast's with different soil groups and varieties showed that chloro-organic compounds added to the soil in amounts usually used in the control of soil pests have a positive effect of the yield of agricultural crops. The reason for such an increase in yield is attributed by some investigators (2, 10, 15) to the direct stimulating effect of chloro-organic compounds on plants, and by others (17) to the elimination of the harm done by insects. Without denying the effect of both these factors, we must note that they are not the only ones. The effect of chloro-organic preparations on crop yield is very varied and must be considered from the following points of view:

1. The direct effect of chloro-organic compounds on the plant organism which causes quantitative and qualitative changes in it.
2. The indirect effect of chloro-organic compounds, which change the nutritional regime of the soil: a) their effect on the mechanism of the salt uptake by the plants; b) the interaction with the solid phase of the soil, which changes the composition of the soil-solution and, consequently, the process of mineral nutrition; and c) the influence of microbiological processes, which determine the composition of the soil solution and plant nutrition even more.
3. The indirect effect of chloro-organic compounds on the yield of cultivated plants as a result of the elimination of pests harmful to plants.

As the investigations of Grigor'yeva (3) have shown a regrouping of the composition of the soil fauna in the podzolic zone takes place under the effect of hexachlorane in such a direction that the sharp decrease of the number of plant-killing insects is accompanied by an increase in the number of certain groups of beneficial soil forming saprophages, earthworms in particular.

The investigations of Ryzhkova (14), and Sazonov and Fedorova (16) showed that the addition of hexachlorane to the soil also affects the regrouping of the entire composition of the microflora, intensifying the physiological activity of some groups (nitrifying) and inhibiting the activity of other groups (denitrifying) of microorganisms.

If the effect of chloro-organic compounds on soil fauna and microflora, as well as their direct effect as plant stimulants has been examined in the literature, the problem of the direct chemical and physicochemical effect of hexachlorane and heptachlor on the soil has not been studied sufficiently yet.

¹This work was done with the participation of the personnel of the All-Union Institute of Plant Conservation and the All-Union Institute of Sugar Beet.

As early as 1936 Mishustin (7) voiced the opinion, which has been confirmed experimentally, that antiseptics promote the entry into solution of nutrient compounds available to plants. In adding chloropicrin to the soil, Mishustin came to the conclusion that "during this period (i. e., during the first 7 days — S. P.) the amount of water-soluble organic substances strongly increased, which is difficult to explain under the given conditions by the activation of biological activity. Evidently we are faced here with the chemical or physicochemical effect of the antiseptic on the organic complex of the soil" (7, p. 213).

In working for many years on the problem of the use of chlor-organic compounds in soil, we also came to the conclusion that along with other factors (stimulating effect, and the regrouping of the composition of the fauna and microflora), affecting the yield of agricultural crops, there is a direct chemical and physicochemical effect of chlor-organic compounds on soil, which promotes an increase in available nutrients in it. This is confirmed by the following experiment. Extracts were prepared from various soils. The soil was treated for 3 minutes with distilled water in one case, with a solution of hexachlorane in another, and with a solution of heptachlor in the third. The extracts were analyzed for: dry residue, ignition loss, mineral residue, water-soluble humus, and water-soluble calcium (Table 9).

As we can see from Table 9 more soluble substances were removed in the extract after the treatment of the soil with solutions of hexachlorane and heptachlor than after treatment with distilled water. In this case the effect of the microbiological factor on the removal of water-soluble substances was eliminated since the soil was shaken with

distilled water and solutions of hexachlorane and heptachlor for 3 minutes. Different amounts of water-soluble substances were extracted from various soils by solutions of hexachlorane and heptachlor.

As our investigations showed (11), chlor-organic compounds are very stable in the soil and decompose very slowly. The compounds are removed from the soil primarily as a result of their passing into the soil solution. But since the solubility of the foregoing compounds in water is very low, they are preserved in the soil for a very long time. Under natural conditions when chlor-organic compounds are added to the soil the same processes apparently take place as we have observed in the laboratory experiments. From this it follows that a larger amount of available compounds can be expected in areas treated with chlor-organic compounds than in non-treated areas. This is confirmed by analyses of soil samples collected in experimental plots 4 months after the addition of hexachlorane to the soil.

The data in Table 10 show that the amount of water-soluble humus, calcium, and P_2O_5 increased under the influence of the treatment of the soil with hexachlorane.

Hexachlorane has no substantial effect on the sum of adsorbed cations, the pH, and hydrolytic acidity. The amount of total humus does not change either.

Conclusions

1. Chlor-organic compounds, added to the soil in amounts ordinarily used for the control of soil-inhabiting pests, increase the yield of agricultural crops.

Table 9

Influence of hexachlorane and heptachlor on the availability of organic and mineral compounds in the soil

Content of substances, mg/100 g of soil	Podzolic sandy loam, Kirishi rayon, Leningrad Oblast'		Alluvial coarse clay loam, Kingisepp rayon, Lenin- grad Oblast'		Clay loam chernozem, Kamensk ray- on, Cherkassk Oblast'		Podzolic clay loam. Vsevol- skiy rayon, Leningrad Oblast'		Leached clay loam cherno- nozem, Smel- yanskiy rayon Cherkassk O'.	
	Substances passed through									
	With water	With hexach. solu.	With water	With hexach. solu.	With water	With hexach. solu.	With water	With hexach. solu.	With water	With hepta- chlor solu.
Total amount of water- soluble substances	75	89	28	109	57	120	67	100	59	92
Ignition loss	26	44	14	58	30	69	38	51	29	40
Total amount of soluble mineral substances	49	146	15	51	26	50	28	49	30	52
Water-soluble humus	10	15	14	18	18	22	10	13	11	20
Water-soluble calcium	2	6	5	13	7	19	3	4	7	13

Table 10

Influence of hexachlorane on the physicochemical properties and on the mobility of the elements of the soil complex (4 months after the addition of hexachlorane to the soil). Soil - leached, clay loam chernozem in the Stalin kolkhoz, Kamensk rayon, Cherkassk Oblast'

Rate of application of industrial hexach. kg/ha	pH of the water extract	Sum of adsorbed cations	Hydrolytic acidity	Total humus, %	Water-soluble humus, g/100 g	Water-soluble calcium	Water-soluble P ₂ O ₅
		meq/100 g				mg/100 g	
Control	6,60	26,4	2,4	3,10	0,0505	12,9	3,0
10	6,62	26,2	2,4	3,05	0,0608	13,4	3,9
20	6,69	26,8	2,3	3,10	0,0624	13,4	4,0
30	6,59	26,6	2,4	3,10	0,0690	14,4	5,3

Note: Comma represents decimal point.

2. One of the reasons for the positive effect of chlor-organic compounds on yield (in addition to others) is the change in the chemical and physicochemical processes which take place in the soil, namely:

a) the increase in the total amount of water-soluble substances; b) the increase of water-soluble humus; and c) the increase of water-soluble calcium and P_2O_5 .

These compounds have no noticeable effect on the total adsorbed cations, hydrolytic acidity, pH, and total humus.

3. The effect of chlor-organic compounds on plants depends on the water regime and mineral nutrition of the soil.

4. The effect of chlor-organic compounds on plants when used as insecticides must be considered in conjunction with soil conditions.

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LEACHING OF SALINE SOILS IN THE PIEDMONT ZONE OF SOUTHERN KAZAKHSTAN

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Kazakhstan occupies second place in our country in the amount of irrigated lands. Irrigated land in southern Kazakhstan comprises one third of the arable land and irrigated agriculture plays the major role in the economy of agricultural production.

More than 500,000 hectares of irrigated land are found in the piedmont zone of southern Kazakhstan. This zone is characterized by steep slopes and strongly dissected irrigated massifs. The efficiency of irrigation systems in the foregoing zone is low and varies from 0.30-0.50. As a result of this a large amount of irrigation water is shed from the fields and lost by evaporation and filtration.

Many of the irrigated lands in the Alma-Ata, Dzhambul', and Southern Kazakhstan Oblast's (2, 3) are becoming water-logged and salinized because of the rise of strongly mineralized ground water. A number of engineering irrigation systems are in disrepair (2).

Irrigation practice shows that in the present technical condition of irrigation systems and the usual misuses of water, mineralized ground water begins to rise and the upper soil layer becomes saline (4). A review of the studies conducted shows that the basic method of preventing the salinization of the active soil layer is leaching in conjunction with the natural or artificial drainage of ground water (1, 4).

Rozov (5) studied the effectiveness of leaching saline irrigated lands in this zone as early as in 1931. The Scientific-Research Institute of Water Economy of the Kazakh Academy of Agricultural Sciences has been conducting studies on the saline lands of the Alma-Ata Oblast' since 1956 for the purpose of developing certain methods and rates of irrigation.¹

The experiments were made at the base station of the Institute and in the "Kzyl-Tu" kolkhoz, Ili rayon. The experimental area is located in the piedmont zone of the Trans Ili

Ala-Tau. It is characterized by a sharply continental climate with a hot, dry summer and a cold winter. The long-time annual precipitation average is slightly more than 200 mm. The average annual temperature is 8.1°C. The sum of positive temperatures during the growing period is 3313°C. Evaporation during the same period is 808 mm.

The upper soil layers of the experimental area (0-20 cm) are represented by medium clay loam, underlain by sandy loam and sands. The water-physical properties of the soil materials of the area under study are presented in Tables 1 and 2. Ground water is close to the surface (0.5-2.0 m) and drops in summer to a depth not more than 2.5 m. Its mineralization reaches up to 20 g/liter of salts in the dry residue. The soils of the experimental area have a chloride-sulfate type of salinization. The chemical composition of the root zone of the soil is shown in Table 3.

The maximum hygroscopicity of the soil is high not only because of the texture of the soil (Table 2), but also because of the degree of its salinization (Table 3).

The experimental area where the profile was taken is located in a field² which was formerly abandoned solonchak covered by salt resistant weeds (Fig. 1).

0-10 cm. Dark, easily muddied, containing many salt inclusions, becomes brightly colored when treated with phenolphthalein. Carbonates are absent.

10-20 cm. The transition is gradual, slightly diffuse. Insignificant amount of carbonate inclusions.

20-50 cm. Dark, porous. Many salt inclusions.

50-80 cm. Yellow, clayey. Insignificant amount of salt inclusions, mist, no Na_2CO_3 .

The infiltration capacity of soils in the

¹The investigations have been conducted under the supervision of the author by junior scientist I. I. Badenko and laboratory technicians A. Fedorova and N. Butina.

²The profile was described by I. I. Badenko.

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Table 1

Water-physical properties of the soil

Layers, cm	Parti- cle dens- ity	Bulk density g/ cm ²	Poros- ity, % of vol- ume	Maxi. molec- ular wa- ter ca- pacity	Maxi. hygro- scopic- ity	Ratio of maximum molecular water ca- pacity to maximum hygro- scopicity
				% of weight of absolutely dry soil		
0—10	2,47	1,25	54,9	16,3	5,3	3,1
10—20	2,80	1,28	54,3	16,2	4,8	3,4
20—40	2,79	1,30	53,5	14,8	5,9	3,0
40—50	2,80	1,34	52,2	19,8	2,6	3,7
50—70	2,84	1,30	42,2	20,0	6,1	3,2
70—90	2,83	1,00	54,1	21,5	6,1	3,5

Note: Comma represents decimal point.

Table 2

Particle-size composition of soil, %

Layers, cm	Particle diameter, mm							Physical clay
	1—0,25	0,25—0,1	0,1—0,05	0,05—0,01	0,01—0,005	0,005—0,001	< 0,001	
0—10	1,8	0,3	9,9	52,2	21,8	7,1	6,8	35,7
10—20	1,7	2,1	8,9	50,6	20,0	11,4	5,3	36,7
20—50	0,5	1,0	4,7	74,8	10,4	5,1	3,5	19,0
50—80	0,7	0,5	1,8	83,5	7,0	3,8	2,7	13,5

Note: Comma represents decimal point.

experimental area is very low, as was to be expected. According to the data of V. I. Levakov, the average infiltration coefficient of the soils in the area under study is 0.4 m/day. The drainage discharge modulus does not exceed 0.3 liter/sec.

The experiment was made in an area covering 8 hectares using 4 different treatments, each replicated 4 times. There were a total of 16 plots. Each plot was 184 m long and 15 m wide. The distance between the plots was 10 m.

Before the experiment was started in autumn of 1956 leaching rates were calculated on the basis of the physical and chemical properties of the soil (Tables 1, 2, and 3). Three leaching rates were selected: 1500 m³/ha, or 1.5 times greater than the moisture deficit, 2000 m³/ha, or twice the moisture deficit, and 3000 m³/ha, or 3 times greater than the moisture deficit. Non-leached plots served as control in each treatment.

The water-salt regime of the soil was studied in special plots, while the regime and

mineralization of the ground water were investigated in observation wells. Phenological observations and the necessary agricultural practices were conducted during the growing period. Similar observations and agricultural practices were conducted in the control plots (non-leached). After leaching, meliorative crops were sown in the plots.

When studying the dynamics of the water-salt regime, soil samples were taken at 4 points along the length of each plot in such a manner that 2 points fell on each half of the plot. Four depth samples were taken and replicated 3 times. The present paper gives average data for each treatment.

Soil samples were taken simultaneously from all the plots in the following periods: before leaching, before planting the crops, after their germination, and during various phases of plant development, i. e., twice a month on the average.

Selection of leaching rates. The first leaching was done in the autumn of 1956 (Fig. 2). The salt content in the root zone of the soil

Table 3
Influence of leaching on the salt content (%) of the soil in the experimental area

Layers, cm	Leaching rate, m ³ /ha	Solid residue		HCO ₃ ⁻		Cl ⁻		SO ₄ ⁼	
		Prior to leaching	After leaching	Prior to leaching	After leaching	Prior to leaching	After leaching	Prior to leaching	After leaching
0—20	1500	2,616	1,088	0,028	0,026	0,048	0,008	1,442	0,721
20—40		1,500	1,013	0,029	0,027	0,016	0,005	0,921	0,641
40—70		1,074	0,782	0,030	0,029	0,012	0,012	0,681	0,541
70—100		1,589	1,589	0,032	0,030	0,010	0,011	0,934	0,982
100—150		1,474	1,492	0,035	0,031	0,006	0,010	0,661	0,982
0—20	2000	2,178	1,226	0,026	0,024	0,022	0,008	1,602	0,460
20—40		1,260	0,912	0,028	0,026	0,008	0,023	0,661	0,574
40—70		0,684	0,664	0,030	0,028	0,010	0,017	0,420	0,407
70—100		1,661	1,614	0,032	0,030	0,013	0,012	1,413	0,922
100—150		1,529	1,524	0,032	0,030	0,014	0,011	0,901	0,601
0—20	3000	2,233	1,402	0,027	0,025	0,046	0,018	1,405	0,741
20—40		1,669	1,414	0,029	0,027	0,016	0,027	0,841	0,761
40—70		0,741	0,933	0,030	0,028	0,017	0,023	0,501	0,561
70—100		1,645	1,580	0,032	0,030	0,015	0,012	0,642	0,821
100—150		1,385	1,516	0,033	0,030	0,011	0,012	0,941	0,801
0—20	Without leaching	2,342	—	0,030	—	0,084	—	0,820	—
20—40		1,248	—	0,027	—	0,016	—	0,528	—
40—70		1,400	—	0,028	—	0,025	—	0,528	—
70—100		1,220	—	0,031	—	0,029	—	0,331	—

Note: Comma represents decimal point.

remained high (Table 3). The best result was obtained with a leaching rate of 1500 m³/ha, whereby mainly the upper 40 cm was leached, while salts accumulated in the 70- to 150-cm layer. The leaching water was completely fresh containing 0.248 g/liter salts, 0.001 g/

liter chlorides, and no sulfates in the dry residue.

Before leaching the ground water was at a depth of 2.4 m. Its mineralization reached 20 g/liter in the dry residue. It had a sulfate-

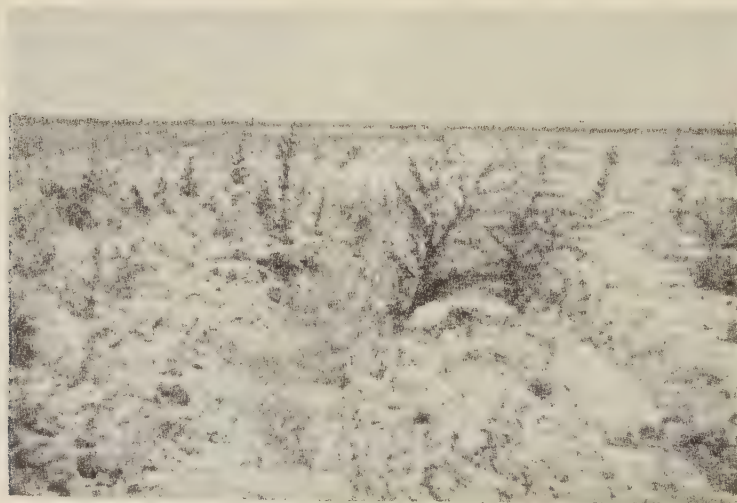


Fig. 1. - View of the surface of the experimental field prior to leaching (author's photograph).

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Fig. 2. - Leaching of the plots in the experimental field (photograph of R. Kvan).

Table 4

Influence of the second leaching in the autumn of 1957 on the dynamics of salts (%) in the soil

Layers, cm	Leaching rate, m ³ /ha	Solid residue			HCO ₃ ⁻		Cl ⁻			SO ₄ ⁻		
		Prior to leaching	After leaching	Amt. of salt removed, % of initial cont.	Prior to leaching	After leaching	Prior to leaching	After leaching	Amt. of salt removed, % of initial cont.	Prior to leaching	After leaching	Amt. of salt removed, % of initial cont.
0—20	1500	1,268	0,836	33,8	0,020	0,017	0,027	0,005	81,4	0,841	0,494	45,2
20—40		1,380	0,712	48,5	0,022	0,020	0,016	0,009	43,6	0,534	0,297	44,1
40—70		1,028	0,540	47,5	0,022	0,028	0,008	0,005	37,7	0,312	0,221	28,1
70—100		1,636	1,336	18,8	0,030	0,026	0,018	0,012	33,3	0,667	0,446	24,3
Average		1,328	0,856	37,2			0,017	0,007	49,0	0,588	0,364	37,9
0—20	2000	1,356	0,728	47,0	0,018	0,016	0,053	0,004	81,2	0,697	0,403	42,1
20—40		1,296	0,840	35,4	0,020	0,015	0,016	0,006	62,5	0,592	0,451	23,6
40—70		1,016	0,424	59,3	0,022	0,015	0,013	0,009	36,9	0,317	0,163	46,4
70—100		1,548	1,192	23,2	0,028	0,026	0,014	0,011	21,5	0,634	0,460	26,5
Average		1,303	0,796	41,2	—	—	0,024	0,007	49,5	0,547	0,369	34,8
0—20	3000	1,764	1,212	31,2	0,020	0,018	0,045	0,008	82,2	0,653	0,465	29,2
20—40		1,244	0,660	46,7	0,022	0,020	0,014	0,011	21,3	0,566	0,352	37,5
40—70		0,812	0,480	47,8	0,024	0,023	0,009	0,007	22,2	0,518	0,276	46,1
70—100		0,352	1,236	—	0,028	0,025	0,016	0,008	50,0	0,673	0,512	23,8
Average		1,293	0,897	41,9	—	—	0,021	0,008	44,0	0,602	0,599	39,1

Note: Comma represents decimal point.

chloride composition. After leaching the content of chlorides in the ground water increased sharply and the ground water rose on the average to 1.5 m. The rise was greatest in the plot with a leaching rate of 3000 m³/ha.

At the time of sowing (April 1957) a certain increase in the salt content of the soil layer under study occurred as compared to the content after leaching. This is attributable to the rise of the ground-water level, caused

by ample precipitation. But the total content of salts did not exceed 1.5% (in dry residue).

Because of the strong wetting of the upper soil layer, the melioration crops (barley, alfalfa, sunflower) were sown late in the spring of 1957. In the control plots (non-leached) the plants died by June 10. Barley and alfalfa in the tillering stage also died in spite of the fact that the furrows were watered. The salt content in the upper soil layer increased by the end of the growing period, as a result of which the yield of sunflower seeds was low and could not be used to determine the effectiveness of one or the other leaching rate.

The foregoing facts made it necessary to drain the soil and leaching waters naturally and to leach the experimental area again. To improve drainage, temporary drainage ditches up to 1 m deep were dug between the plots. Leaching was conducted from October 11 to November 5, 1957. Each leaching rate was applied in several applications. The effect of the second leaching on the removal of salts from the root zone of the soil is shown in Table 4.

Here the removal of salts is noticeable to a depth of 0.70 m. The maximum amount of salt (as dry residue) was removed from the upper 1 m of the soil by leaching at the rates of 1500-2000 m³/ha. The content of sulfates in the layer from 0.70-1.0 m increases the second year after leaching.

The leaching depth increases under the effect of temporary drains and leaching in several applications. The use of leaching rates in several applications promotes the better desalinization of the root zone as compared to leaching in one application (Table 5).

The data in Table 5 confirm the effectiveness of leaching in three applications.

When comparing Table 6 (leaching rate of 2000 m³/ha) with Table 4, we can see that the amount of solid residue and the sulfate content increased somewhat during the autumn-winter period.

Ensilage sunflower seeds, collected in the experimental area in 1957 and soaked in ground water before seeding were planted in the spring of 1958 in the same area.

At the end of the summer of 1958 the sunflowers were harvested for ensilage. The top yield was 505 cntr/ha in the plot with a leaching rate of 1500 m³/ha, 620 cntr/ha in the plot with a leaching rate of 2000 m³/ha, 605 cntr/ha in the plot with a leaching rate of 3000 m³/ha, and 120 cntr/ha in the control plot. Consequently, leaching at a rate of 2000 m³/ha was most effective. The leached experimental plot can be considered as ready for further melioration for valuable agricultural crops.

Corn was sown in the experimental area in 1959. The corn yield, harvested for ensilage in the milk-wax stage, was 310 cntr/ha in the plot with a leaching rate of 1500 m³/ha, 450

cntr/ha in the plot with a leaching rate of 2000 m³/ha, 405 cntr/ha in the plot with a leaching rate of 3000 m³/ha, while corn hardly germinated in the control plot.

Sugar beets were sown in the area in 1960. Its root yield under the different treatments was, respectively, 360 cntr/ha, 400 cntr/ha, 470 cntr/ha, and 160 cntr/ha (control).

The results of our investigations are in complete agreement with the experiments conducted by Rozov in 1931 in the area under study (5). Rozov also reports that single leaching does not produce a sufficient desalinization of the root zone. Small, repeated rates must be used periodically, which desalinize the soil to a sufficient depth. Leaching promotes the transition from a chloride type of salinization to a sulfate type, which reverts to a chloride

Table 5

Dynamics of sulfates (%) during application of the leaching rate in several steps

Layer, cm	Initial	Rate used		
		In one	Intwo	Inthree
		Applications		
0 — 20	1,442	0,721	0,494	0,465
20— 40	0,921	0,641	0,297	0,252
40— 70	0,681	0,541	0,221	0,276
70—100	0,934	0,430	0,446	0,412
Average	0,994	0,708	0,364	0,355

Note: Comma represents decimal point.

Table 6

Salt content in soil in the spring of 1958 prior to sowing crops, %

Layers, cm	Solid resi- due	Alkalinity		Cl ⁻	SO ₄ ⁼
		From ordin- ary carbon- ates	Total		
Leached plots					
0— 20	0,873	None	0,021	0,004	0,156
20— 40	0,802	"	0,016	0,011	0,190
40— 70	0,694	"	0,026	0,012	0,105
70—100	0,809	"	0,012	0,014	0,251
Control plots (non-leached)					
0— 20	1,080	None	0,020	0,012	0,399
20— 40	1,364	"	0,020	0,030	0,509
40— 70	1,016	"	0,021	0,031	0,426
70—100	0,788	"	0,030	0,017	0,303

Note: Comma represents decimal point.

Table 7

Dynamics of the salt regime during soil leaching

Layer, cm	Salt content, %								
	Solid residue			Cl ⁻			SO ₄ ⁼		
	Prior to leaching	After leaching	% rmvd. from initial	Prior to leaching	After leaching	% rmvd. from initial	Prior to leaching	After leaching	% rmvd. from initial
1-100	1,164	0,359	69,1	0,016	0,007	56,3	0,594	0,242	59,2

Note: Comma represents decimal point.

type on secondary salinization.

When verifying the results obtained in 1958 we made an experiment in the "Kzyl-Tu" kolkhoz in the Ili rayon of the Alma-Ata Oblast', which borders on the base station of the Institute, and where a progressive salinization of irrigated areas takes place. The leaching rate used was 2000 m³/ha (Table 7).

The yield of corn tops in the milk-wax stage was 250 cntr/ha in the control plot and 930 cntr/ha in the leached plot here. The better effect of leaching here is attributable to the good natural drainage of the field and the lesser degree of initial salinization. In 1959 the kolkhoz leached a large land area with the cooperation of the Institute to be used for corn.

As we can see, the regulation of saline irrigated lands (depending on the degree of salinization and ground-water drainage) in the piedmont zone of the Trans-Ili Ala-Tau is a difficult process. Therefore, farms having saline land take great care to observe all the rules of salinization control, using the experience gained by the Institute and the "Kzyl-Tu" kolkhoz.

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USE OF RADIOACTIVE COMPLEXES AS WATER TRACERS IN HYDROLOGICAL SOIL INVESTIGATIONS

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Various indicators, the so-called tracers, have been used for a long time to solve a number of soil hydrology problems, such as the movement of soil and ground water, infiltration, the mechanism of the movement of moisture in soils, etc.

The substances used as tracers must not react with the soils or change their properties. They must be resistant to physical, chemical and biological weathering, while the methods of detecting them in very small concentrations must be as simple, reliable, and convenient as possible. The tracers used under field conditions and which enter ground water and water bodies must be harmless to animal organisms and to plants.

Inorganic salts and organic dyes are usually used as water tracers, but they only partly fulfill the foregoing requirements. One of the major disadvantages of such tracers is the necessity of using them in relatively large amounts (sufficient for detecting the tracer after it has been diluted by soil and ground waters), which may distort both the conditions of the medium under study and the process of water transport. Therefore radioactive isotopes have been incorporated into tracers in the last 10-15 years, which makes it possible to decrease the concentration of the tracer millions of times because of the unusual sensitivity of radiometric methods of analysis. Only a few compounds manufactured by the chemical industry can be used as tracers in hydrological soil investigations. For instance, compounds which dissociate in water and are tagged by the cation cannot be used because of the property inherent to soils and soil materials of sorbing cations from the soil solution.

The S^{35} , I^{131} , and Br^{82} in the form of alkaline sulfate salt and halide anions, as well as tritium (H^3) introduced into water, are the major radioactive tracers used in hydrological investigations at the present time. However, these compounds also do not always satisfy the requirements of tracers both because of their

chemical properties and the radiation emitted by the foregoing isotopes. For instance, the sulfur isotope in the form of $H_2S^{35}O_4$ which is used frequently emits soft γ -rays and therefore must either be removed from the soil samples by means of a water extract (2) during quantitative measurements, or samples of the same volume must always be used as targets (1), which makes analysis more time consuming and requires special safety measures (open radiating source).

Moreover, soils have a certain exchange capacity as far as anions are concerned and therefore partly adsorb SO_4^{--} .

A widely used tracer is I^{131} , but it can only be used in quantitative investigations in the presence of an iodine carrier, since in the opposite case a considerable part of it (up to 50%) is lost as a result of oxidation which leads to the formation of free iodine. This fact increases safety requirements during work with I^{131} and makes its use for obtaining quantitative data more difficult.

In recent years the radioactive isotope of hydrogen — tritium — has been used more and more in hydrological investigations. Its content in soil and ground water has now increased because of its removal from the atmosphere by precipitation. In certain investigations such increased tritium concentration as compared to the "pre-bomb" days can be used directly, in others tritium water must be introduced. At the present time instruments have been developed which make it possible to detect insignificant H^3 concentrations in water by its soft γ -radiation. It must be noted, however, that the method of measurement is time consuming as yet, since radiometric analysis of water for H^3 must be preceded either by the electrolysis of the sample, or tritium must be converted into an organic compound, or the water under study must be completely evaporated. Moreover, H^3 is not suitable for the study of such problems of soil hydrology which require a distinction to be made between the movement of moisture in the liquid and the vapor phase, because tritium, forming part of the water, will evaporate and condense with it, in contrast to other indicators.

¹The work was done under the supervision of Candidate of chemical sciences, M. K. Mel'nikova.

The comparatively small selection of radioactive tracers suitable to hydrological soil investigations forces us to find means of increasing the number of radioisotopes suitable for this purpose. The report (7), which appeared in the literature on the suitability of chelates incorporating a radioactive cation as water tracers, is of interest in this respect. Such a complex-former is, for instance, sodium ethyldiaminetetraacetate (trilon B), which forms chelates, together with metal ions, which are soluble in water and stable within a wide range of pH. The metal in such compounds, being bound inside the complex, does not manifest ionic properties and does not become involved in exchange reactions with the medium, provided the stability constant of such a chelate is higher than the stability constants of trilon B complexes with the exchangeable cations of the soil and the cations of the soil solution.

The stability of trilon B complexes with certain cations, including those characteristic of soil solutions and the adsorption complex of the soil, can be judged from the following data (Table 1).

On the basis of these data we may expect that several cations to the left of Al^{+++} in the

table are suitable as water tracers for ordinary soil conditions as far as the stability of their chelates is concerned.

We verified under laboratory conditions the suitability of the Co^{60} chelate as a water tracer. As we know, Co^{60} emits hard (1.33 mev) γ -radiation, which makes it possible, for instance, to follow the movement of soil moisture without taking the sample from the experimental device or from the soil, and widens the possibilities of study.

The Co^{60} isotope cannot always be used in field experiments because of its relatively long half-life (5.24 years). In this case other cobalt isotopes, such as Co^{57} and Co^{58} can be used, which have a half-life of 270 and 72 days, respectively.

The preparation of tagged chelates is simple and consists of adding a small amount of trilon B to the solution of radioactive salt.

To determine the suitability of the Co^{60} chelate as a tracer we made 2 series of experiments. In the first series we added 10 ml of water containing 50 μc of $Co^{60} (NO_3)_2$ and 30 mg of trilon B per liter to each 2 g sample of 3 sod-podzolic soils of various textures (from coarse clay

Table 1

Stability of ethylenediaminetetraacetic acid with ions of a number of elements (6)

Logarithm of the stability constant	Cu^{++}	Ni^{++}	Zn^{++}	Cd^{++}	Co^{++}	Al^{++}	Fe^{++}	Mn^{++}	Ca^{++}	Sr^{+++}	Ba^{++}	Na^{++}
18,80	18,62	16,50	16,46	16,31	16,13	14,33	14,04	10,96	8,69	8,63	7,76	1,66

Note: Comma represents decimal point.

Table 2

Influence of trilon B on the sorption of $Co^{60}(NO_3)_2$ by 3 soils

Sample	Desorption with respect to the initial specific activity								
	Without trilon B			With trilon B			$Na_2S^{24}O_4$		
	Counts/min. ml	%	% sorp- tion	Counts/min. ml	%	% sorp- tion	Counts/min. ml	%	% sorp- tion
Initial solution	38400	100,0	—	38400	100,0	—	7670	100,0	—
Sod-podzolic coarse clay loam soil	5870	15,3	84,7	39380	102,5	—2,5	6630	86,5	13,5
Same, gleyey medium clay loam soil	5200	13,5	86,5	39590	103,1	—3,1	6280	82,1	17,9
Same, gleyey coarse clay loam soil	3120	8,1	91,9	39310	102,2	—2,2	6850	89,6	10,4

Note: Comma represents decimal point.

loam to coarse clay). A solution of the same activity, but without trilon, was used as the control. The test tubes with the suspension were shaken in a rotary vibrator for 2 hours, centrifuged for 1 hour, and then a sample was taken from the transparent sediment and counted in a radiometric scintillation counter with a sodium iodide crystal. The results of the measurement, as compared to the activity of the initial solution, are presented in Table 2, which gives the results of similar experiments with $\text{Na}_2(\text{S}^{35}\text{O}_4)$ for comparison.

The data in Table 2 indicate that the Co^{60} bound in the chelate is not sorbed by the soils studied and exhibits an insignificant negative adsorption² in contrast to the S^{35}O_4 anion, which is retained to a certain degree (10%-15%) in the soil.

The results obtained are confirmed by the other series of experiments in which $\text{Co}^{60}(\text{NO}_3)_2$ solution with and without trilon was slowly (1 ml/hr) percolated through a 10 cm column of air-dry soil. The specific activity of successive portions of the percolate was compared with the activity of the initial solution (Fig. 1). The results of the experiment show that the cobalt chelate moves freely with the water and does not become sorbed by the soils studied.

When conducting long-term investigations the problem of the resistance of the trilon complex to biological and especially microbiological influences becomes essential. Trilon B is an organic compound containing nitrogen, which increases the possibility of its decomposition by soil microflora (our attention was

drawn to this fact by V. M. Klechkovskiy). This difficulty applies less to soil materials which are more inert as far as microflora is concerned, as well as to investigations on the movement of moisture at low temperature, which inhibits the life activity of microorganisms.

The data obtained by us during the study of the movement of soil moisture under the influence of the temperature gradient may serve as an example of the use of the cobalt chelate for hydrological soil investigations.

As we know, the rate of moisture movement toward lower temperatures in many cases exceeds the rate of vapor diffusion, calculated by the Fick formula, modified for a porous medium (4). At the same time it was shown (2) that the rate of vapor diffusion through a dry soil or a hydrophobic layer agrees well with that calculated by the Fick method, and, secondly, that at soil moistures higher than maximum hygroscopic moisture part of the moving moisture does not pass through the hydrophobic layer and accumulates in front of it.

The participation of the vapor phase in the thermal moisture movement can be determined experimentally by tracing the liquid phase. Therefore, the soil used in the experiments was brought to a set initial moisture with water containing $100 \mu\text{c/liter}$ of $\text{Co}^{60}(\text{NO}_3)_2$ and 50 mg/liter of trilon B. After the completion of the experiment (during which a constant temperature difference was maintained at the ends of

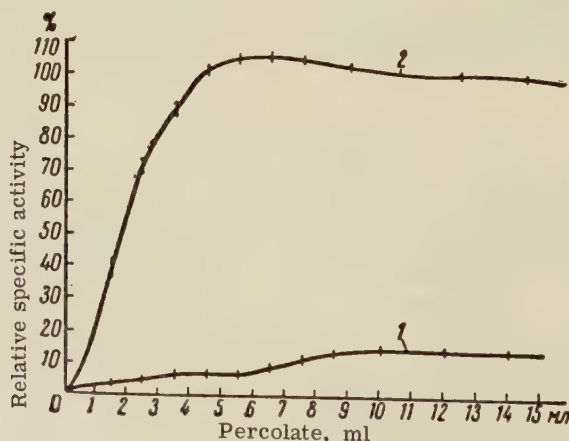


Fig. 1. - Influence of trilon B on the mobility of Co^{60} in the soil.
1 - $\text{Co}^{60}(\text{NO}_3)_2$; 2 - same + trilon B

²The negative adsorption is apparently caused by the presence of the so-called non-dissolving volume in the soil. Our data, however, do not permit us to judge of it more definitely, since the effect is within experimental error.

the column) the column was taken apart and the final moisture content of soil was determined in a drying oven with samples of approximately equal weight, placed in standard aluminum cans. Then the dry samples were distributed in an even layer in the same cans by means of a

cylindrical tamper (breaking up the aggregates) and the activity of the sample was measured by placing the can directly on the crystal of the scintillator in a special holder, which always fixed the can in the same position with respect to the crystal. To verify the effect of the position of the sample relative to the light, the can was turned 90° after the first measurement and the activity was measured again. The difference between such measurements did not exceed the statistical counting error. The dependence of activity measurements on the weight of the sample was determined before the experiments. This was done by placing a sample of moist soil into the aluminum can, drying it in an oven, measuring its activity, adding to the sample a new portion of soil of the same specific activity, and measuring again after drying. This procedure was repeated several times (Table 3).

As we can see from Table 3, specific activity decreases somewhat with increasing sample weight as a result of self absorption and poorer geometry. However, even for quantitative studies a difference of 1-2 g in the weight of the samples being compared can be tolerated. In those cases when accuracy requirements are very rigid it is desirable to take equal samples or reduce the results of the measurements to

Table 3

Relation between the weight of radioactive soil and the specific activity measured

Dry sample, g	counts/min	counts/min, g	%
3,372	5151	1559	105,9
6,475	9483	1479	100,3
10,146	14946	1472	100,0
13,029	18581	1425	96,8
16,856	23306	1385	84,1

Note: Comma represents decimal point.

a definite sample weight by previous calibration, as it was shown earlier (Table 3).

The results of experiments on the mechanism of soil moisture movement under the influence of a temperature gradient are shown in the diagram (Fig. 2-a). A column of medium clay loam soil was subject for 96 hours to a temperature gradient of 1°C/cm. During the experiment the average rate of moisture movement was 4.4×10^{-7} g/cm² sec, while the theoretical rate of vapor diffusion (2, formula 1) for the experimental conditions is 0.8×10^{-7} g/cm² sec. If we attribute the observed excess rate of the moisture flow over vapor diffusion primarily to movement in the liquid phase, the general tendencies of moisture and tracer redistribution during the experiment must be equal. This, however, was not observed. In contrast to the change in moisture, the tracer concentration decreases at the cold and increases at the hot end of the column, which is apparently attributable to circulation processes in the course of which moisture, transported by the thermal current to the cold of the column, moves back in the liquid form under the effect of the moisture gradient. The increase in the concentration of the tracer at the hot end of the column, which is observed even at a very low initial soil moisture, is probably associated with the phenomenon of thermal osmosis (4).

These data confirm the results of other investigators (6) and make them more reliable, since in the paper mentioned macroamounts of strong electrolytes (NaCl) were used as a tracer, which made it possible to explain the distribution of the tracer by incidental ionic effects.

The nature of the thermal transport phenomenon will be discussed by us in more detail in another paper. Here we would like to present, in addition, the results of experiments in which we used a hydrophobic layer and a radioactive tracer. A column of medium clay loam soil, divided in the middle by a 10 mm

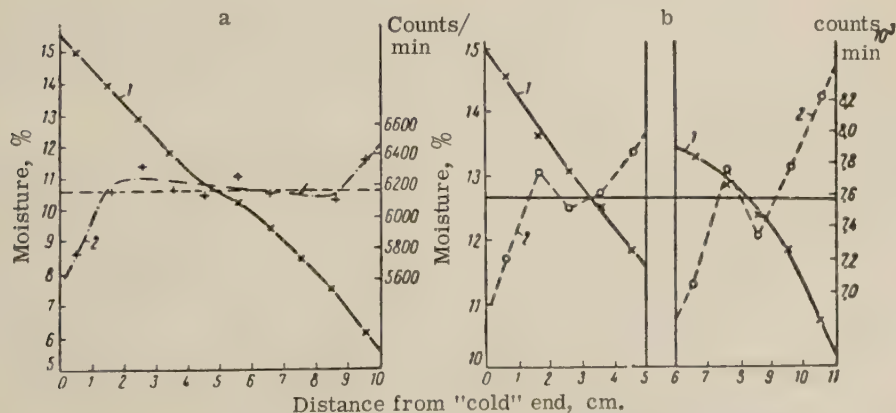


Fig. 2. - Movement of soil moisture and the liquid phase tracer in the soil under the influence of a temperature gradient.

a - solid columns; b - columns with a hydrophobic layer. 1 - H₂O; 2 - Co⁶⁰.

layer of hydrophobic sand, was subjected as in the previous experiments to the action of a temperature gradient of $1^{\circ}\text{C}/\text{cm}$ (Fig. 2 b). A comparison of this graph with the preceding graph shows that that part of the moisture which accumulates in front of the hydrophobic layer does not move toward it primarily by a transient liquid current. The explanation of the results obtained apparently lies in the following.

Under the given conditions when the soil is not saturated with moisture and the moisture is distributed primarily in the junction fringe the most probable mechanism of the thermal movement of moisture is a series of microprocesses of evaporation and condensation within the pores with the interstitial flow of moisture along the function fringe.

In conclusion let us briefly describe the measuring apparatus used in our studies. All the measurements were made by means of a solid NaI scintillating crystal and an FEU-13 photomultiplier, mounted in a thick shield. The pulses from the photomultiplier were fed to a "Siren" discriminator with a discrimination threshold of 3 v, and then to a PS-1-PS-10,000 scaling circuit ("Flocks"). Such an apparatus can work under a spectrometric regime and makes it possible, if needed, to distinguish separately in one sample the activity of two or more radioactive tracers, differing in the nature of their radiation.

Even though the foregoing results do not solve the problem of the suitability of radioactive complexes for any soils (especially for saline soils and soils rich in iron), we still believe that attention should be paid to this promising method of using radioactive tracers in hydrological soil investigations.

Conclusions

1. Laboratory investigations have shown that a complex of trilon B with Co^{60} is not

sorbed by the podzolic soils studied and moves freely in them with the water flow. This points to the possibility of using chelates of the type of trilon B together with a radioactive isotope as a water tracer in hydrological soil investigations.

2. A method of using a chelate of Co^{60} during studies of the movement of soil moisture under the effect of a temperature gradient is described in which moisture and radioactivity are determined in one and the same sample with sufficient accuracy for quantitative hydrological investigations.

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LABORATORY DETERMINATION OF THE BIOLOGICAL ACTIVITY OF THE SOIL

G. M. OGANOV

At present, many investigators pay more and more attention to the biological activity of the soil when evaluating its fertility and study the intensity of the CO_2 liberation by the soil.

We will not discuss the methods proposed for this purpose, but will only note that at present the most widely accepted method of determining biological activity is that developed by Shtatnov.¹ It basically consists in that the soil surface is covered with a cylindrical vessel and the carbon dioxide liberated by it is bound with a weak alkali solution. Under laboratory conditions the author recommends keeping the soil sample under a bell containing a weak solution of NaOH or $\text{Ba}(\text{OH})_2$, dyed with phenolphthalein. Two to three hours later the alkali is titrated with hydrochloric acid and the amount of CO_2 , liberated from a unit area of the soil surface, is calculated.

The Shtatnov method is simple enough, but leaves room for errors. Because the alkali solution cannot be shaken after the soil sample is placed under the bell, the values obtained for CO_2 are too low. Moreover, it is difficult to use a thermostat during the first incubation when making mass determinations.

To determine the biological activity of the soil we used a wide-neck conical flask (400 ml) with a stopper provided at its lower end with a wire bracket for suspending a crucible (of 25 ml capacity) with soil (Fig. 1). A glass tube is placed in the crucible with its end in washed sand.

A soil sample (20 g) passed through a sieve with openings 2 mm in diameter is used for the determination. The moisture content and moisture capacity of the soil are determined beforehand. Depending on the moisture at which the biological activity of the soil must be determined, the amount of water which must be added to the soil sample is calculated, taking into account the moisture it contains.

The sample in the crucible is moistened with

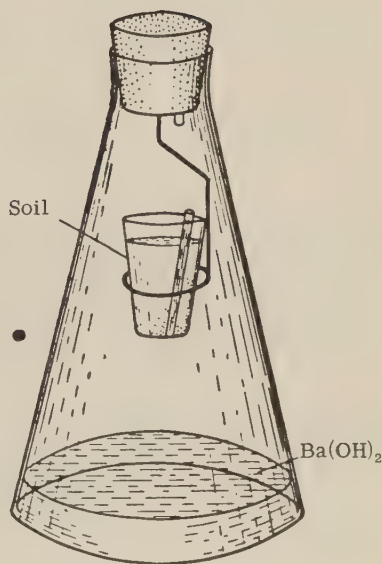


Fig. 1. - General view of the flask with the suspended crucible and the barium hydroxide for the determination of the biological activity of soil.

a pipette through the tube which is placed in the drainage layer. If the experimental conditions require incubation at a moisture of 60% of the full moisture capacity (and the latter for the given soil is 40%) then 100 g of soil must contain 24 ml of water, and 20 g of soil, 4.8 ml. If the air-dry sample in the crucible contains 1.2 g of moisture, then $4.8 - 1.2 = 3.6$ ml of water must be added before the determination is made.

To bind the liberated CO_2 , 25 ml of 0.1 N $\text{Ba}(\text{OH})_2$ or NaOH with 2 drops of phenolphthalein are poured in the bottom of the flask.

The flask with the soil and the fixing solution is placed for the incubation period (from 4 to 20 hours) in a thermostat at a temperature of $27^\circ\text{--}28^\circ\text{C}$. To each flask 2 ml of a 50% BaCl_2 solution are added and

¹V. I. Shtatnov. Method of determining the biological activity of soils. Dokl. VASKHNIL. No. 6. 1952.

Table 1

Comparative results of determining the biological activity of soils, CO₂ mg/kg of soil

Soil	Depth, cm	Shtatnov method		Proposed method	
		Soil without glucose	Soil + glucose	Soil without glucose	Soil + glucose
Podzolic yellow earth, slightly gleyey	0—20	69	210	73	214
Same, B horizon after plowing in the year the determination was made	35—60	33	61	32	65
Same, B horizon turned over to clay on the surface 4 years ago	35—60	25	117	30	132
Clay-bog, medium clay loam	0—80	160	528	157	583
Same, illuvial horizon, fine clay loam	20—45	90	311	87	315
Clay-bog, medium clay loam	0—20	153	641	153	669
Same, illuvial horizon, fine clay loam	20—35	129	613	139	642

titrated with an HCl solution until the pink coloration disappears. At the same time a similar flask with an alkali solution and without soil is placed in the thermostat for a blank test. The solution at the bottom of the flask is carefully shaken two or three times during this period by a light rotating movement.

The calculations are made in the following way. Let us assume that 18.2 ml of the 0.1 N HCl were used for titrating the barium hydroxide in the control flask and 16.3 ml in the test flask. The difference is 1.9 ml. By multi-

plying 1.9 ml by 2.2 mg of CO₂, corresponding to 1 ml of alkali, we obtain 4.18 mg of CO₂ for a sample of 20 g. As reduced to 1 kg of soil the amount of CO₂ liberated will be $4.18 \times 1000:20 = 209$ mg.

A comparison of the results with the data obtained by the Shtatnov method showed a sufficiently close agreement (see Table 1).

The advantage of the method described consists in that it makes it possible to conduct a greater number of analysis simultaneously and in the simplicity of the determinations.

RESOLUTIONS OF THE SEVENTH ALL-UNION CONFERENCE ON SOIL EROSION CONTROL

S. S. SOBOLEV and G. A. PRESNYAKOVA

The conference, held in Moscow from December 6-10, 1960, was organized by the V. V. Dokuchayev Soil Institute, Academy of Sciences, USSR, the Ministry of Agriculture of the USSR, the All-Union Lenin Order Academy of Agricultural Sciences; the All-Russian Society for the Cooperation in Nature Conservation and the Landscaping of Settled Areas; the All-Union Scientific-Technical Society of Agriculture and Forestry; and the All-Union Society of Soil Scientists.

The conference approved the following measures of an interzonal nature for the control of soil erosion by water and wind.

1. The organization of erosion control in the territory using topographic maps and the separation of areas subject to various degrees of water and wind erosion on the basis of soil investigations.

2. Prohibiting the plowing, the planting of agricultural crops in rows, and the cultivation of fallow along slopes and in the direction of erosive winds in level areas subject to severe wind erosion.

3. Reinforcing and planting forests in gullies, sands, and strongly eroded steep slopes and mountain slopes, and planting forests on soils not suitable for agricultural purposes in all zones of the country where conditions are favorable for it. In reinforcing gullies the simplest hydrologic structures must be installed in conjunction with forest plantations.

4. Introducing major soil protective crop rotations and buffer strips of perennial grasses in areas subject to strong deflation or washing. Stubble must be left at the surface of fields during plowing without a moldboard, and in certain cases strip farming must be practiced. Moreover, terraces must be established on steep slopes and under mountain conditions.

5. Prohibiting plowing of lands subject to erosion, steep slopes, and coarse-textured soils without taking special erosion control measures.

6. Establishing grass areas and reinforcing depressions in the immediate vicinity of gullies and ravines along which there is a con-

centrated flow of meltwater and rain water. Establishing grass areas on steep slopes and sands.

Grass areas and buffer strips can be established by plowing up the sod of perennial grasses, measuring beforehand the necessary width, and leaving unplowed depressions and buffer strips.

7. Constantly checking the state of the micro-relief of plowed fields leveling sedimented channels and regulating surface runoff.

8. Regulating the grazing of cattle on sands and sandy loams, on overgrown and half-overgrown sands, ravines, steep slopes and mountain slopes, and prohibiting the cutting of forests on them by methods which promote erosion.

9. Protecting dirt and graded roads from washing out and deflation.

10. Taking measures to prevent water and wind erosion when planning the reclamation of new lands for agriculture, and industrial and civil construction.

In individual soil-climatic and agricultural zones and regions, in each kolkhoz and sovkhos, every land user must take special measures suitable for local conditions, based on scientific knowledge and experience. The combination of these measures with the general interzonal measures creates zonal systems and local complexes for the control of soil erosion by water and wind which must be part of zonal agricultural systems.

A major task of scientific-research and experimental establishments, as well as institutions of higher learning, is to develop and elaborate zonal systems and complexes for the control of soil erosion by water and wind (taking into account local natural and economic conditions) to eliminate as rapidly as possible the destructive erosion of fields and pastures in Oblast's, provinces, and republics.

The most effective soil erosion control measures and their combinations must be discussed and selected in oblast's, provinces, and republics in order that the zonal complexes of measures be an organic part of agricultural systems

and systems of land management.

To help in the development of practical complexes for the control of soil erosion by water and wind the Conference recommends the following systems of erosion control for the individual zones of the country, which supplement the foregoing interzonal erosion control complexes.

For the flat areas of the USSR.

I. In the chernozem belt of the European USSR the principal erosion control measures are agricultural and forest melioration measures:

a) Among the agricultural measures the most important are the regulation of surface meltwater and rain runoff and the increase of soil moisture, such as: 1) various methods of plowing which promote moisture accumulation, including deep cultivation; 2) the diking of autumn-plowed and fallow fields for the winter with temporary earth banks for the retention of meltwater; 3) discontinuous ridging; 4) snow retention, the regulation of snow melting, and other methods of retaining meltwater in the fields; 5) cultivation of square-nest plantings first along and then across the slope; the cultivation of level areas subject to wind erosion first along and then across the direction of erosive winds; and 6) use of water-retention measures in hay fields and pastures, such as diking, multi-stage catchwork irrigation, narrow ditching (covering the ditches), etc.

b) An integral part of the erosion control system in the chernozem belt is agricultural forest melioration practices, which, for gullies, must be partly combined with hydrologic measures. They include: the creation of water-regulating shelterbelts along the gullies and ravines, shelterbelts around ponds and water reservoirs, and the planting of forests in gullies in combination with the simplest hydrologic structures.

Soil erosion control must be differentiated within the chernozem belt of the European USSR. In those regions of Moldavia where snow is scant and where rain erosion predominates, while meltwater has little significance in the destruction of the soil, methods of protecting the soil must be adapted to the period of heavy rains. Here winter crops are sometimes superior to spring crops in their protective effect. In more moist regions where beets are grown in the forest steppe, and where perennial grass yields are high and occupied fallows are effective, erosion control measures must be different from those used in the drier eastern and southern regions of the Ukraine and the Central Chernozem Belt, and especially the dry southeast - the Volga region. Post harvest and companion crops can be planted over wide areas in those regions of the Kuban' and Stavropol' which have a long, warm, and moist autumn. All these subzones and regions of the chernozem belt of the European USSR require that zonal and regional control measures against soil erosion by water and wind be worked out in detail at the locality.

II. In the chernozem belt of the Asiatic

USSR, in Siberia, and in Kazakhstan the principal methods of erosion control are agricultural methods directed toward the regulation of surface runoff and the increase of soil moisture.

Here erosion control by forest melioration is not as common as in the European USSR. Work on the establishment of forest shelterbelts must be expanded in regions where conditions are favorable to forests and will ensure permanent forest plantations. In dissected relief water erosion control measures serve at the same time as measures for the protection of soil against wind erosion.

III. The principal erosion control measures in the chernozem and the arid chestnut soil belt of the European USSR with slightly dissected, level relief, but subject to wind erosion, such as the southern Ukraine, the Northern Caucasus, and some areas in Bashkiriya, the Southern Urals, and the Volga region, are agricultural and forest melioration measures.

1. They must include: high-level of agricultural practice, which ensures the accumulation of moisture in the soil, the even and rapid germination and development of agricultural crops, which protect the soil against wind erosion; the planting of winter and spring crops during the best (agricultural) periods; and the refusal to plant winter crops too late.

2. Reduction of the wind velocity in the air layer near the ground by leaving stubble at the soil surface in autumn-plowed and fallow fields during plowing without a moldboard; grain crops are cut high for the better protection of the soil and snow retention.

3. Creation of a wind resistant cloddy surface in clay loam soils by proper cultivation, and the rolling of plantings only with ring rollers, which do not pulverize the surface of the field (flat rollers pulverize the soil and promote wind erosion).

4. Crossed and narrow-row sowing; in areas with water erosion the second run of the seeder during crossed sowing is made across the slope and in level areas, across the direction of erosive winds.

5. Deeper planting of seeds.

6. Furrow sowing of grain and row crops.

7. Introduction of soil-protecting crop rotations.

8. Protection of the soil from deflation with windbreaks and forest shelterbelts; combining the protective effect of forest belts with that of windbreaks from plants with tall stalks and the listed agricultural practices; in fields where tall crops are grown, such as corn, sunflower, etc., windbreaks of 2-3 rows must be left.

9. Reduction of dust collection areas from which dust and small aggregates are blown away and saturate the air layer near the ground during black storms by the division of fields by buffer strips of perennial grasses, windbreaks, forest belts, and the practice of strip

farming where conditions are more difficult, i. e., alternating strips with grain crops, row crops, and perennial grasses, the width of which is determined by the intensity of wind erosion.

10. Testing on a large scale of the method recommended by P. A. Kostychev which consists of planting with the winter crops spring annuals (winter cress, rape, mustard, etc.), which die from frost without seeding themselves and protect the soil and winter plantings from deflation and at the same time ensure snow retention. This method has recently been tested in Bashkiriya and gave positive results.

11. When planting forests on sand it is recommended that the soil be cultivated deeply in narrow strips without a moldboard.

12. As an experiment narrow ditches should be dug in autumn in pastures, hay fields, and perennial grass plantings, and covered.

IV. In the chernozem and arid chestnut belt of the Asiatic USSR with slightly dissected level relief, but subject to wind erosion, such as the Northern Kazakhstan, Western Siberia, Kulunda and Krasnovarsk Province, agricultural measures are also effective, except for measures for the protection of winter crops, which are not grown here as a rule. Forest shelterbelts are of great importance in these regions, even though they are not common yet. Good results were obtained from forest belts in the control of wind erosion in Western Siberia and in the Altay Province.

The most important of the agricultural measures here are: 1) the prevention of the pulverization of the soil during plowing by substituting the disc tiller, which pulverizes the soil, with implements without moldboards and paring plows with a moldboard when cultivating the soil prior to sowing and taking care of the fallow, especially on coarse-textured and calcareous soils, which lose their structure easily; 2) when wind erosion is severe live or dead cover (stubble, plant residues) must always be kept at the surface of the field by limiting or eliminating moldboard plowing in the autumn and moldboard plowed clean fallow by replacing normal plowing in the autumn and turning the sod over by plowing without a moldboard in autumn to a depth of 20-22 cm and keeping as much stubble in the fields as possible, by the extensive use of stubble for the retention of the first snow, rapid soil thawing, better absorption of meltwater into the soil, the creation of conditions ensuring maximum soil moistening and the control of wind erosion; the elimination of all other autumn cultivation which destroys the stubble in the fields; the retention of stubble in fallow fields by plowing and cultivation with implements without a moldboard; and the substitution of flat roller by ring rollers; 3) use of grain disc drills with rollers for the local rolling of each row (soil aggregates remain between the rows and protect the field against wind erosion) and paring plow-seeders for the simultaneous pre-sowing cultivation of the soil and plantings over stubble (with any amount of stubble at the surface

of the fields); 4) introduction of strip cropping when planting perennial grasses in short-term fallow and fallow — row-crop rotations; where wind erosion is severe grass-arable soil-protection systems with perennial grasses must be introduced; 5) protection of windward slopes, summits of hills, and coarse-textured and calcareous soils against wind erosion must be reinforced; areas subject to severe wind erosion must be excluded from crop rotation and converted into grass areas; grass areas must be established in narrow successive strips of a width which can be worked by single, double and triple seeding units; the unplowed protective strips can be plowed only when the grasses in the planted strips have taken hold and have thickened out; 6) grass areas or forest must be established on plowed hilly sands and loose sandy soils which have already been subjected to the action of wind; these areas must not be incorporated into cultivated fields; and 7) it is recommended that the scientific-research and experimental establishments of Siberia and Kazakhstan conduct large-scale tests on various methods of plowing fallow and autumn-plowed fields without a moldboard, retaining as much stubble as possible.

V. For the non-chernozem zone with sod-podzolic soils and for the northern part of the forest steppe it is recommended that: 1) clean fallow be replaced by occupied and green-manured fallow; winter crops be planted on fallow in areas where these crops are grown and erosion by meltwater is severe; 2) post harvest and undersown crops be used; 3) perennial legumes and legumes and grass mixtures be used in all crop rotations; 4) acid soils be limed, and fertilizers and green manure be used extensively; 5) water discharge furrows be made when necessary in excessively wet areas; 6) snow melting be regulated by compacting the snow in strips and other means; 7) autumn-plowed and fallow fields be ridged and diked for the winter on slopes which suffer from droughts caused by erosion; and 8) forests be planted on the shores of water reservoirs.

Because of the industrial and agricultural reclamation of the mountain regions of the USSR, their role in the national economy has sharply increased. At the present time about 9 million hectares of plowland and about 63 million hectares of hay fields and pastures are located in the mountain areas of the USSR. Mountain forests play an important role in the protection of the soil and water retention. Mountains with their forests are huge moisture condensers. Many rivers, on which hydroelectric power stations are built, which are the basis of the development of a number of regions, originate in them. The water from mountain rivers is used to irrigate the most important agricultural regions of the USSR.

Soil erosion, destructive flash floods, and floods develop when mountain regions are improperly used.

The common features in the control of soil erosion, flash floods, and floods in the mountain regions of the USSR include:

1. The introduction of a special organization

of kolkhozes, sovkhoses, state forests, and state lands in mountain areas, which takes into account the requirements of soil erosion and flash flood control.

2. Regulation of cattle grazing in alpine and subalpine meadows, and the forest zone, established cattle trails, watering places, and sheds, the introduction of pasture rotations and a corral system of grazing, prohibiting their overgrazing and use in the early spring.

3. Improvement of damaged and eroded mountain hay fields and pastures by seeding valuable meadow and pasture grasses, fertilization, and by taking various measures for supplying moisture to dry mountains.

4. Improvement of mountain forest management, the planting and protection of mountain forests, and promoting their natural reforestation.

5. Limiting the utilization of forests (of all types) to a set amount of cutting (prohibiting overcutting).

6. Prohibition of forest exploitation by methods which promote erosion, sharply limiting clear cutting in mountain forests and forbidding it on slopes steeper than 35° ; establishment of forest shelterbelts along rivers and streams, as well as in areas with fine-textured and stony soils.

7. Use of new techniques of logging, which ensure the protection of the soil from erosion, the preservation of the regrowth, as well as the preservation of the soil-protecting, water-conserving, and water-regulating role of mountain forests.

8. Especially strict regulation of forest utilization and soil erosion control in places most subject to flash floods, as well as on fine soil underlain by solid rock, and in areas where conditions are unfavorable to the growth of forests.

The Conference requests the Council of Ministers of the USSR to examine the problem of the transfer of kolkhoz forests of importance to erosion control in mountain areas, as well as in the plains, to the state forest reserve or to establish in them the same utilization and conservation regime as in state forests.

9. Reconstruction of inferior forest plantations by introducing valuable trees and shrubs, the planting of trees in clearings and in sparse stands.

10. Prohibiting the plowing of new lands for planting annual agricultural crops on slopes steeper than $10-50^{\circ}$; prohibiting the growing of agricultural crops without using the complex of soil erosion control measures (see above — interzonal complex of erosion control measures).

11) Use of the simplest hydrologic measures for runoff regulation on slopes and channels in flash flood basins.

I. For mountainous, subtropical tea-growing areas, such as Georgia, Azerbaydzhan, and the Krasnodar Province (the Caucasian shore of the Black Sea), it is recommended that: 1) the soil be cultivated deeply; 2) tea shrubs be planted horizontally, trellis-fashion; 3) soil-protective cover plants be used, including green manure crops; 4) organic and mineral fertilizers be widely used; 5) drainage furrows and sodded waterways be established; 6) slopes be terraced for citrus crops, orchards, and vineyards; 7) agricultural crops be planted horizontally in strips, using buffer strips; and 8) drainage furrows be established and waterways discharge be sodded.

II. In moist mountain areas of the Northern and Western Caucasus, the western part of the Crimea, the Carpathians, Kazakhstan, the Altay, Sayan, and the Eastern Baykal region it is recommended that: 1) soil-protective crops rotations be introduced, including meadow-pasture rotation; 2) agricultural crops be planted horizontally on slopes; 3) temporary as well as permanent buffer strips be established with a narrow strip of cultivated soil; 4) drainage and water-retention furrows and ditches be established; and 5) fruit-berry crops be planted in horizontal strips and on terraces.

III. The following recommendations are made for the arid mountain regions of Central Asia, Eastern Georgia, Azerbaydzhan, Armeniya, Eastern and Southern Caucasus, and in the Trans-Caucasus and the eastern part of the Crimea: 1) the plowing of slopes for annual agricultural crops be limited and prohibited in strongly eroded areas, using them for grass areas and perennial plantings; 2) agricultural measures be used for soil erosion control in crop rotation fields on non-eroded and slightly eroded slopes up to $6^{\circ}-8^{\circ}$ steep; soil-protective crop rotations, including perennial grasses, be used on slightly and moderately eroded slopes $8^{\circ}-10^{\circ}$ steep, using strip farming; and that permanent buffer strips be used in strip farming and terrace farming on moderately and severely eroded slopes $10^{\circ}-15^{\circ}$ steep; 3) the system of agricultural measures be used for the retention of rain and meltwater (deep plowing, diking, discontinuous furrows, water-collecting depression, etc.); 4) overgrown, wild-growing fruit plantings be improved and inferior forest stands be reconstructed by planting more valuable trees (walnut, apple, myrobalan plum, pistache, almond, etc.); 5) forests and soils be protected from erosion in basins subject to flash floods, which are dangerous here; that forests be planted in flash-flood channels and alluvial fans; 6) the simplest hydrologic structures be erected on the slopes and channels of flash-flood basins and flash floods be discharged harmlessly.

IV. The most important measures in regions where erosion is caused by irrigation are the regulation of the water flow, the proper arrangement of furrows (taking relief into account), the extensive use of soil-protecting crop rotations, and mixed (companion) crops; the use of contour buffer strips, etc.; and the change to sprinkler irrigation if erosion is severe.

Measures for soil erosion control along the vertical mountain belts of individual republics

and regions, applicable to the peculiarities of the crops being grown, must be worked out in detail.

The Conference believes that the first and major task of scientific-research and experimental establishments, and institutions of higher learning is the detailed development of zonal and regional systems or complexes of organizational-economical, agricultural, forest melioration, and hydrologic measures for the control of soil erosion by water and wind, and the establishment of their economical effectiveness. These complexes of measures must be an integral part of agricultural systems and agricultural management as a whole, and be worked out and introduced in our country.

The detailed development and verification of the effectiveness of zonal systems of erosion control and the improvement of individual water and wind erosion control measures applicable to local conditions are only possible with the establishment of a geographical network of experimental-demonstration farms — kolkhozes and sovkhozes. A network of 100-150 demonstration farms (kolkhozes and sovkhozes) must be established in the next 2-3 years in the major soil-climatic and agricultural zones and regions of the USSR (including mountain regions). There must be 3-4 farms in each region where erosion control measures, applicable to local soil-climatic and economical conditions, are practiced. The Conference recommends that the responsibility for creating such farms, and for conducting all the scientific-research work according to a unitary method on these farms, and the introduction of the latest scientific achievements and experience into production, must be given first of all to territorial (regional) state agricultural experiment stations, and also to zonal and leading scientific-research institutes (for a period of not less than 10 years). Taking the demonstration farms as an example, we must comprehensively study, verify, and evaluate the suitability and effectiveness of individual erosion control measures, taking local conditions into account, as well as whole systems of erosion control applicable to each zone and region. These demonstration farms must serve as the best example of measures for the control of soil erosion by water and wind. At the same time the measures taken and the experiments made at these farms will give scientific-research establishments a wealth of material for generalization and the further development of erosion control systems and theoretical bases for the control of soil erosion.

In addition to this we must improve individual soil erosion control measures applicable to local natural-economic conditions, study their economic effectiveness and develop new methods, taking into account the increasing requirements of agriculture and changing conditions of mechanization.

We must pay special attention to the development of zonal methods for the protection of the soil from water and wind erosion when growing more productive row crops, such as corn, sugar beets, sunflower, potatoes, etc. Such measures as furrow planting under ordinary cultivation and cultivation without a moldboard with the conservation of the stubble,

discontinuous furrows and narrow slits between the rows of crops deserve detailed study in various zones. We must test mixed plantings, the new method of increasing buffer strips by dense seeding in strips, and the application of fertilizers in strips in the more moist regions. It is very important to develop zonal systems of plowing without a moldboard, using stubble for the protection of the soil from wind and water erosion, which would be applicable to various soil-climatic conditions.

We must work out complex zonal recommendations for the rational utilization of eroded soils, for increasing their productivity, for increasing production per unit area and lowering its cost.

The Conference has requested from the Ministry of Agriculture of the USSR that it entrust the Scientific-Research Institute of Mechanization (VIM) with the development of a system of machines and implements for soil erosion control.

Scientific research on soil erosion control involves the solution of theoretical problems using the achievements of agricultural biology, chemistry, physics, and other related disciplines, bolder experimentation and the search for new means for eliminating destructive soil erosion by water and wind.

Experimental institutes and farms must study various crop varieties and wild grasses (Agropyrum, couch grass, Bermuda grass, Kochia, etc.), which are most suitable in various regions for the retention of eroded soils, blowing sands and gullies, and organize the collection of these grasses and their propagation in sufficient quantities.

We must organize and expend scientific-research (including methodological) work on soil erosion control in major and zonal institutes, at territorial experiment stations, creating departments, laboratories, special stations and experiment points on erosion control, on the basis of the network of demonstration sovkhozes.

Scientific achievements and experience on soil erosion control must be advertised more strongly in the press, movies, the radio, as well as the Exhibit of the Achievements of the National Economy of the USSR (VDNKH), and at exhibits in individual republics, Oblast's, and rayons, and in mobile exhibits.

Special sections in the journals "Zemledeliye" and "Lesnoye khozaystvo" must be devoted to soil erosion control.

In order to study the processes of soil erosion systematically, generalize the experience gained in our country and abroad, develop methods for the control of soil erosion, and introduce the newest scientific achievements into production, we must intensify our scientific-research work on soil erosion control at Ministry of Agricultural Institutes of the USSR and the RSFSR, and in the academies of agricultural sciences of the Union Republics, in zonal institutes, in the Academy of Sciences of the USSR, and in the academies of sciences of Union Republics. The coordination of all the scientific-

research work on soil erosion must be entrusted to the V. V. Dokuchayev Soil Institute, and the work of the permanent Interdepartmental Scientific Methods Commission in this Institute must be resumed.

The Conference approved the staff of the permanent Interdepartmental Scientific Methods Commission on soil erosion control, which in-

cludes 107 people.

The Commission must hold its assemblies not less than once a year and must organize a bureau for current work, consisting of: I. V. Tyurin as the chairman, S. S. Sobolev, N. S. Sokolov, and A. T. Panfilov as the substitute chairmen, G. A. Presnyakova as the scientific secretary, and 32 members.

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